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ABSTRACT

This teacher's guide aims to develop an understanding among students grades 5 through 9 of the physical reality of drug use. Contents include: (1) "Brain Anatomy"; (2) "Nerve Cells and Neurotransmission"; (3) "Effects of Drugs on the Brain"; (4) "Marijuana"; (5) "Opiates"; (6) "Inhalants"; (7) "Hallucinogens"; (8) "Steroids"; (9) "Stimulants"; (10) "Nicotine"; and (11) "General Unifying Activity." (YDS)

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MIND OVER MATTER

THE BRAIN'S RESPONSE TO DRUGS

ED 462 291

TEACHER'S GUIDE

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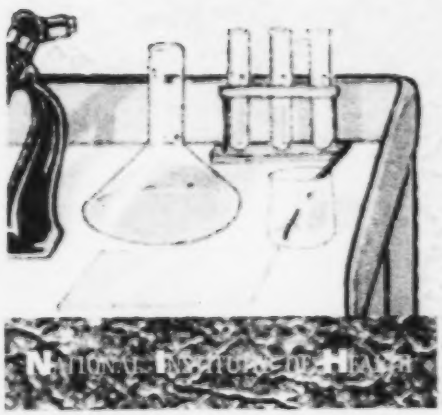

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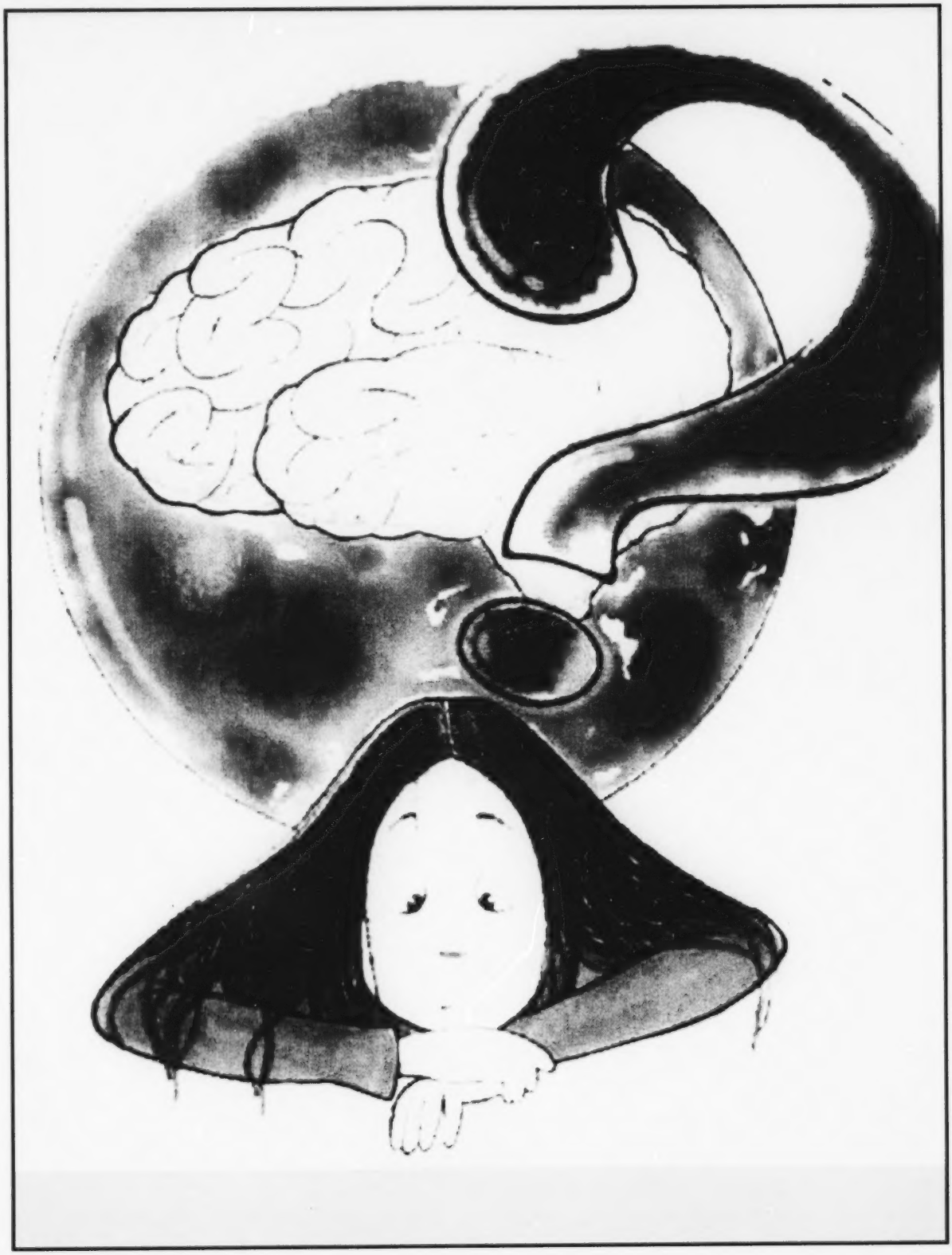

Mind Over Matter

TEACHER'S GUIDE

U.S. Department of Health and Human Services
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Office of Science Policy and Communications
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5600 Fishers Lane
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Contents

Introduction 1

Background Information

- Brain Anatomy 2
- Nerve Cells and Neurotransmission 3
- Effects of Drugs of Abuse on the Brain 5

Marijuana 7

Opiates 11

Inhalants 17

Hallucinogens 21

Steroids 25

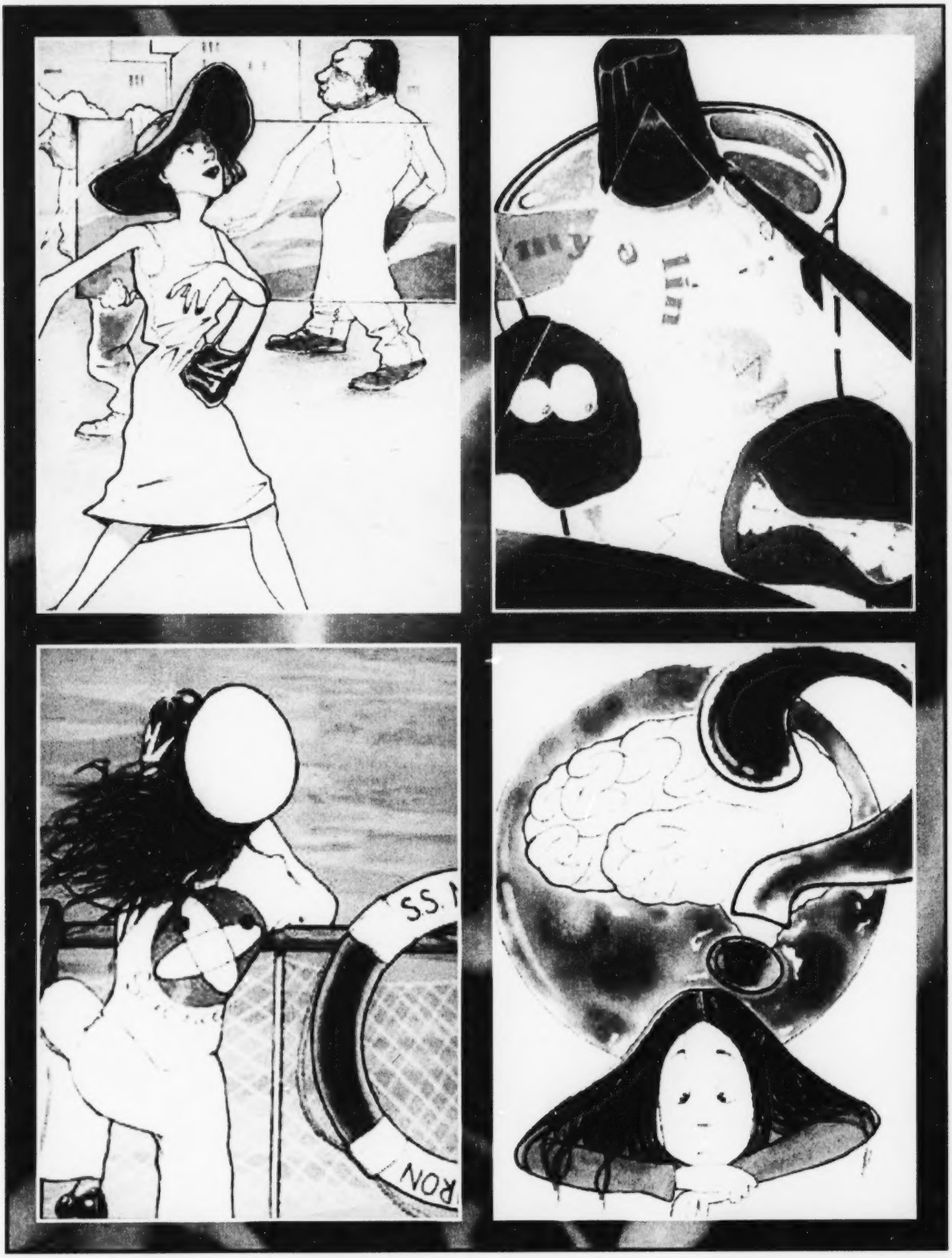
Stimulants 27

Nicotine 31

General Unifying Activity 38

Appendicies

- Resources 39
- Reading List 40
- Figures 1-7 (copyable) 41



Introduction

"MIND OVER MATTER" TEACHER'S GUIDE

This is the teacher's guide for the "Mind Over Matter" series. This exciting new neuroscience education series, developed by the National Institute on Drug Abuse (NIDA), a component of the National Institutes of Health, is designed to encourage youngsters in grades 5-9 to learn about the biological effects of drug abuse on the body and the brain.

The "Mind Over Matter" series includes six colorful, over-sized, glossy magazines, each of which is devoted to a specific drug or drug group; including stimulants, hallucinogens, inhalants, marijuana, opiates, and steroids. Each of the magazines describes the effects of specific drugs or drug types on the anatomy and physiology of the brain and the body. These educational materials further elaborate on the way in which these drug-induced changes affect both behaviors and emotions.

The background information and lesson plans contained in this guide, when used in combination with the magazines in the series, will promote an understanding of the physical reality of drug use, as well as curiosity about neuroscience. The guide suggests a brain anatomy educational activity that can be used throughout the curriculum (see page 30), as well as additional activities for each of the six drug topics. Of course, you are encouraged to develop your own relevant lesson plans.

Note: Full-size versions of Figures 1-7 are located in the back of this guide.

BRAIN ANATOMY

The brain consists of several large regions, each responsible for some of the activities vital for living. These include the brainstem, cerebellum, limbic system, diencephalon, and cerebral cortex (Figure 1).

The brainstem is the part of the brain that connects the brain and the spinal cord. It controls many basic functions, such as heart rate, breathing, eating, and sleeping. The brainstem accomplishes this by directing the spinal cord, other parts of the brain, and the body to do what is necessary to maintain these basic functions.

The cerebellum, which represents only one-eighth of the total weight of the brain, coordinates the brain's instructions for skilled repetitive movements and for maintaining balance and posture. It is a prominent structure located above the brainstem.

On top of the brainstem and buried under the cortex, there is a set of more evolutionarily primitive brain structures called the limbic system (Figure 2). The limbic system structures are involved in many of our emotions and motivations, particularly those that are related to survival, such as fear,

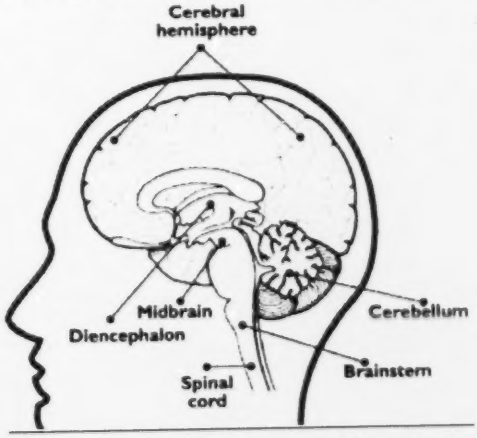


FIGURE 1 This drawing of a brain cut in half demonstrates some of the major regions of the brain

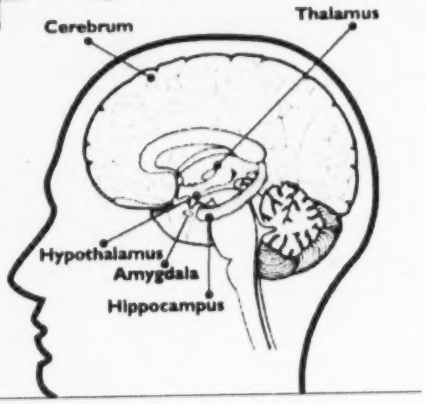


FIGURE 2 This drawing of a brain cut in half demonstrates some of the brain's internal structures. The amygdala and hippocampus are actually located deep within the brain, but are shown as an overlay in the approximate areas that they are located.

anger, and emotions related to sexual behavior. The limbic system is also involved in feelings of pleasure that are related to our survival, such as those experienced from eating and sex. Two large limbic system structures called the amygdala and hippocampus are also involved in memory. One of the reasons that drugs of abuse can exert such powerful control over our behavior is that they act directly on the more evolutionarily primitive brainstem and limbic structures, which can override the cortex in controlling our behavior. In effect, they eliminate the most human part of our brain from its role in controlling our behavior.

The diencephalon, which is also located beneath the cerebral hemispheres, contains the thalamus and hypothalamus (Figure 2). The thalamus is involved in sensory perception and regulation of motor functions (i.e., movement). It connects areas of the cerebral cortex that are involved in sensory perception and movement with other parts of the brain and spinal cord that also have a role in sensation and movement. The hypothalamus

is a very small but important component of the diencephalon. It plays a major role in regulating hormones, the pituitary gland, body temperature, the adrenal glands, and many other vital activities.

The cerebral cortex, which is divided into right and left hemispheres, encompasses about two-thirds of the brain mass and lies over and around most of the remaining structures of the brain. It is the most highly developed part of the human brain and is responsible for thinking, perceiving, and producing and understanding language. It is also the most recent structure in the history of brain evolution. The cerebral cortex can be divided into areas that each have a specific function (Figure 3). For example, there are specific areas involved in vision, hearing, touch, movement, and smell. Other areas are critical for thinking and reasoning. Although many functions, such as touch, are found in both the right and left cerebral hemispheres, some functions are found in only one cerebral hemisphere. For example, in most people, language abilities are found in the left hemisphere.

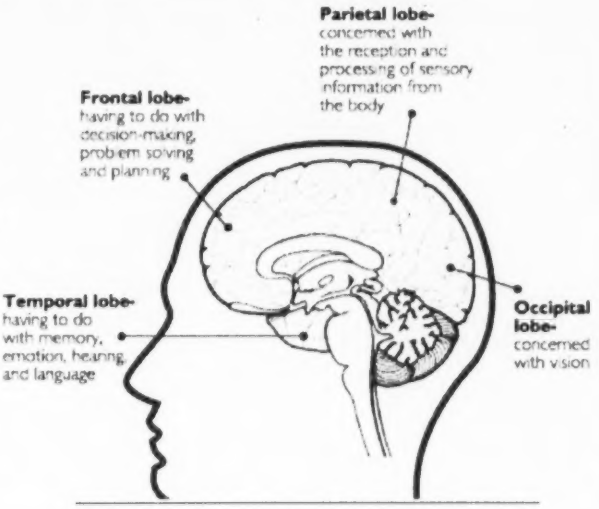

Parietal lobe-
concerned with the reception and processing of sensory information from the body
Frontal lobe-
having to do with decision-making, problem solving and planning
Temporal lobe-
having to do with memory, emotion, hearing, and language
Occipital lobe-
concerned with vision

FIGURE 3 This drawing of a brain cut in half demonstrates the lobes of the cerebral cortex and their functions

NERVE CELLS AND NEUROTRANSMISSION

3

The brain is made up of billions of nerve cells. Typically, a neuron contains three important parts (Figure 4): a central cell body that directs all activities of the neuron; dendrites, short fibers that receive messages from other neurons and relay them to the cell body; and an axon, a long single fiber that transmits messages from the cell body to the dendrites of other neurons or to body tissues, such as muscles. Although most neurons contain all of the three parts, there is a wide range of diversity in the shapes and sizes of neurons as well as their axons and dendrites.

The transfer of a message from the axon of one nerve cell to the dendrites of another is known as neurotransmission. Although axons and dendrites are located extremely close to each other, the transmission of a message from an axon to a dendrite does not occur through direct contact. Instead, communication between nerve cells occurs mainly through the release of chemical substances into the space between the axon and dendrites (Figure 5). This space is known as the synapse. When neurons communicate, a message, traveling as an electrical impulse, moves down an axon and toward the synapse. There it triggers the release of molecules called neurotransmitters from the axon into the synapse. The neurotransmitters then diffuse across the synapse and bind to special molecules, called receptors, that are located within the cell membranes of the dendrites of the adjacent nerve cell. This, in turn, stimulates or inhibits an electrical response in the receiving neuron's dendrites. Thus, the neurotransmitters act as chemical messengers, carrying information from one neuron to another.

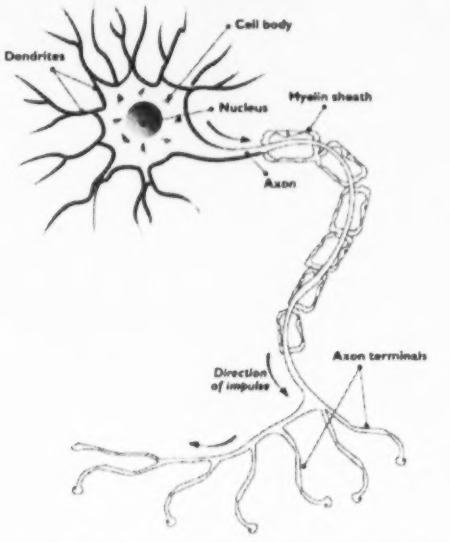


FIGURE 4

There are many different types of neurotransmitters, each of which has a precise role to play in the functioning of the brain. Generally, each neurotransmitter can only bind to a very specific matching receptor. Therefore, when a neurotransmitter couples to a receptor, it is like fitting a key into a lock. This coupling then starts a whole cascade of events at both the surface of the dendrite of the receiving nerve cell and inside the cell. In this manner, the message carried by the neurotransmitter is received and processed by the receiving nerve cell. Once this has occurred, the neurotransmitter is inactivated in one of two ways. It is either broken down by an enzyme or reabsorbed back into the nerve cell that released it. The reabsorption (also known as re-uptake) is accomplished by what are known as transporter molecules (Figure 5). Transporter molecules reside in the cell membranes of the axons that release the neurotransmitters. They pick up specific neurotransmitters from the synapse and carry them back across the cell membrane and into the axon. The neurotransmitters are then available for reuse at a later time.

4

As noted above, messages that are received by dendrites are relayed to the cell body and then to the axon. The axons then transmit the messages, which are in the form of electrical impulses, to other neurons or body tissues. The axons of many neurons are covered in a fatty substance known as myelin. Myelin has several functions. One of its most important is to increase the rate at which nerve impulses travel along the axon. The rate of conduction of a nerve impulse along a heavily myelinated axon can be as fast as 120 meters/second. In contrast, a nerve impulse can travel no faster than about 2 meters/second along an axon without myelin. The thickness of the myelin covering on an axon is closely linked to the function of that axon. For example, axons that travel a long distance, such as those that extend from the spinal cord to the foot, generally contain a thick myelin covering to facilitate faster transmission of the nerve impulse. (Note: The axons that transmit messages from the brain or spinal cord to muscles and other body tissues are what make up the nerves of the human body. Most of these axons contain a thick covering of myelin, which accounts for the whitish appearance of nerves.)

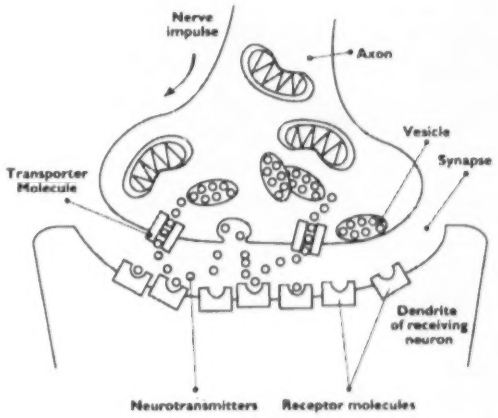


FIGURE 5

EFFECTS OF DRUGS OF ABUSE ON THE BRAIN

Pleasure, which scientists call reward, is a very powerful biological force for our survival. If you do something pleasurable, the brain is wired in such a way that you tend to do it again. Life-sustaining activities, such as eating, activate a circuit of specialized nerve cells devoted to producing and regulating pleasure. One important set of these nerve cells, which uses a chemical neurotransmitter called dopamine, sits at the very top of the brainstem in the ventral tegmental area (VTA) (Figure 6). These dopamine-containing neurons relay messages about pleasure through their nerve fibers to nerve cells in a limbic system structure called the nucleus accumbens. Still other fibers reach to a related part of the frontal region of the cerebral cortex. So, the pleasure circuit, which is known as the mesolimbic dopamine system, spans the survival-oriented brainstem, the emotional limbic system, and the frontal cerebral cortex.

All drugs that are addicting can activate the brain's pleasure circuit. Drug addiction is a biological, pathological process that alters the way in which the pleasure center, as well as other parts of the brain, functions. To understand this process, it is necessary to examine the effects of drugs on neurotransmission. Almost all drugs

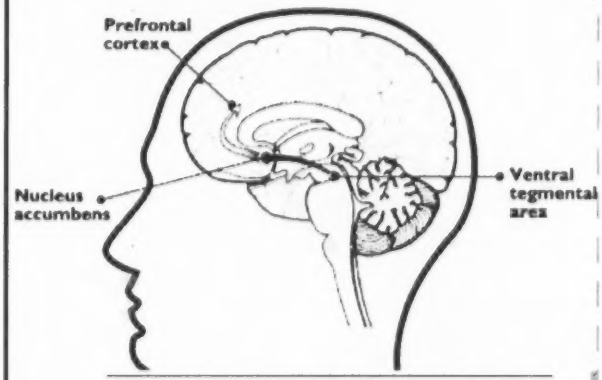


FIGURE 6 This drawing of a brain cut in half demonstrates the brain areas and pathways involved in the pleasure circuit

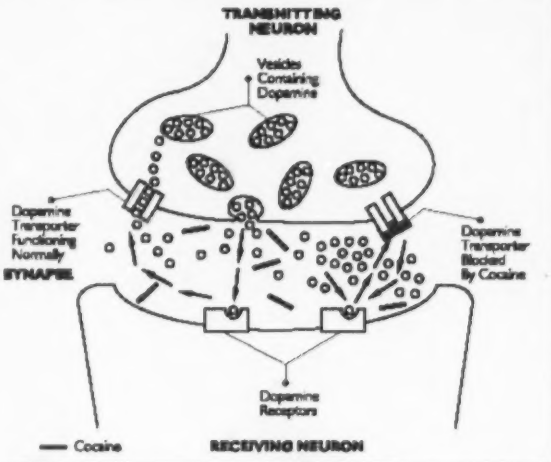
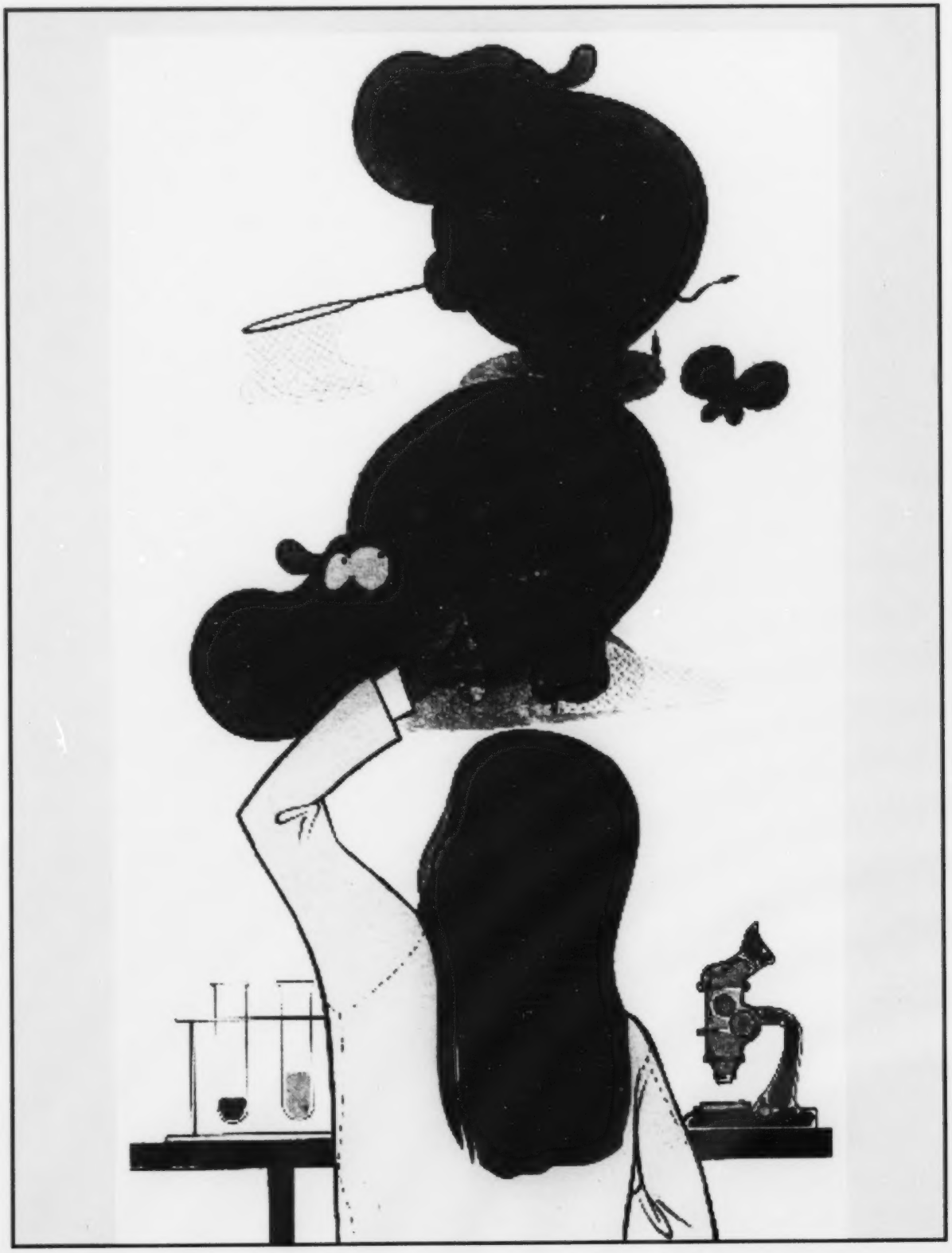


FIGURE 7 When cocaine enters the brain, it blocks the dopamine transporter from pumping dopamine back into the transmitting neuron, flooding the synapse with dopamine. This intensifies and prolongs the stimulation of receiving neurons in the brain's pleasure circuits, causing a cocaine "high."

that change the way the brain works do so by affecting chemical neurotransmission. Some drugs, like heroin and LSD, mimic the effects of a natural neurotransmitter. Others, like PCP, block receptors and thereby prevent neuronal messages from getting through. Still others, like cocaine, interfere with the molecules that are responsible for transporting neurotransmitters back into the neurons that released them (Figure 7). Finally, some drugs, such as methamphetamine, act by causing neurotransmitters to be released in greater amounts than normal.

Prolonged drug use changes the brain in fundamental and long-lasting ways. These long-lasting changes are a major component of the addiction itself. It is as though there is a figurative "switch" in the brain that "flips" at some point during an individual's drug use. The point at which this "flip" occurs varies from individual to individual, but the effect of this change is the transformation of a drug abuser to a drug addict.



BACKGROUND

Marijuana is the dried leaves and flowers of the cannabis plant. Tetrahydrocannabinol (THC) is the main ingredient in marijuana that causes people who use it to experience a calm euphoria. Marijuana changes brain messages that affect sensory perception and coordination. This can cause users to see, hear, and feel stimuli differently and to exhibit slower reflexes.

MECHANISM OF ACTION

THC, the main active ingredient in marijuana, binds to and activates specific receptors, known as cannabinoid receptors. There are many of these receptors in parts of the brain that control memory, thought, concentration, time and depth perception, and coordinated movement.

By activating these receptors, THC interferes with the normal functioning of the cerebellum, the part of the brain most responsible for balance, posture, and coordination of movement. The cerebellum coordinates the muscle movements ordered by the motor cortex. Nerve impulses alert the cerebellum that the motor cortex has directed a part of the body to perform a certain action. Almost instantly, impulses from that part of the body inform the cerebellum as to how the action is being carried out. The cerebellum compares the actual movement with the intended movement and then signals the motor cortex to make any necessary corrections. In this way, the cerebellum ensures that the body moves smoothly and efficiently.

The hippocampus, which is involved with memory formation, also contains many cannabinoid receptors. Studies have suggested that marijuana activates cannabinoid receptors in the hippocampus and affects memory by decreasing the activity of neurons in this area. The effect of marijuana on long-term memory is less certain, but while someone is under the influence of marijuana, short-term memory can be compromised. Further, research studies have shown chronic administration of THC can permanently damage the hippocampus of rats, suggesting that marijuana use can lead to permanent memory impairment.

Marijuana also affects receptors in brain areas and structures responsible for sensory perception. Marijuana interferes with the receiving of sensory messages (for example, touch, sight, hearing, taste, and smell) in the cerebral cortex. Various parts of the body send nerve signals to the thalamus, which then routes these messages to the appropriate areas of the cerebral cortex. An area of the sensory cortex, called the somatosensory cortex, receives messages that it interprets as body sensations such as touch and temperature. The somatosensory cortex lies in the parietal lobe of each hemisphere along the central fissure, which separates the frontal and parietal lobes. Each part of the somatosensory cortex receives and interprets impulses from a specific part of the body. Other specialized areas of the cerebrum receive the sensory impulses related to seeing, hearing, taste, and smell. Impulses from the eyes travel along the optic nerve and then are relayed to the visual cortex in the occipital lobes. Portions of the temporal lobes receive auditory messages from the ears. The area for taste lies buried in the lateral fissure, which separates the frontal and temporal lobes. The center for smell is on the underside of the frontal lobes. Marijuana activates cannabinoid receptors in these various areas of the cerebrum and results in the brain misinterpreting the nerve impulses from the different sense organs.

For many years, it was known that THC acted on cannabinoid receptors in the brain. It was hypothesized that since the normal brain produces these receptors, there must also be a substance produced by the brain itself that acts on these receptors. Despite years of effort, however, the brain's THC-like substance eluded scientists, and whether or not such a substance existed remained a mystery. Finally, in 1992, scientists discovered a substance produced by the brain that activates the THC receptors and has many of the same physiological effects as THC. The scientists named the substance anandamide, from a Sanskrit word meaning bliss. The discovery of anandamide opened whole new avenues of research. For instance, since the brain produces both anandamide and the cannabinoid receptors to which it binds, it was thought that anandamide must play a role in the normal functioning of the brain. Scientists are now actively investigating anandamide's function in the brain. This research will not only help in gaining a greater understanding of how marijuana acts in the brain and why it is abused, but it will also provide new clues about how the healthy brain works.

Marijuana

The discovery of anandamide may also lead to a greater understanding of certain health problems and ultimately to more effective treatments. When made synthetically and given orally, THC can be used to treat nausea associated with chemotherapy and stimulate appetite in AIDS wasting syndrome. It may also be useful for other conditions, including glaucoma. Now that the brain's own THC-like substance has been identified, researchers may soon be able to uncover the mechanisms underlying the therapeutic effects of THC. This could then lead to the development of more effective and safer treatments for a variety of conditions.

Recent research in animals has also suggested that long-term use of marijuana (THC) produces changes in the limbic system that are similar to those that occur after long-term use of other major drugs of abuse such as cocaine, heroin, and alcohol. These changes are most evident during withdrawal from THC. During withdrawal, there are increases in both the levels of a brain chemical involved in stress and certain emotions and the activity of neurons in the amygdala. These same kinds of changes also occur during withdrawal from other drugs of abuse, suggesting that there may be a common factor in the development of drug dependence.

The following activities, when used along with the magazine on marijuana, will help explain to students how these substances change the brain and the body.

9

Marijuana

OBJECTIVES

* **The student will understand the effects of marijuana on brain structures which control the five senses, emotions, memory, and judgment.**
* **The student will use knowledge of brain-behavior relationships to determine the possible effects of marijuana on the ability to perform certain tasks and occupations.**

MARIJUANA ACTIVITY ONE

Review the way in which marijuana use affects brain regions and structures that control the five senses, heart rate, emotions, memory and judgment. Students then randomly select (for example, draw from a hat) an occupation and are asked to act-out, in front of the class, how marijuana use might specifically affect the performance of a person in that occupation. Examples of occupations can include: an airline pilot, a professional basketball player, a doctor, a defense attorney, a truck driver, a construction worker, a waiter/waitress, a politician, etc. Students will identify the brain regions and structures affected by marijuana use, and describe the link between these structures and behavior.

10

OBJECTIVE

* **The student will understand how marijuana interferes with information transfer and short-term memory.**

MARIJUANA ACTIVITY TWO

Read a list of 20 words aloud to the class and then ask students to write down as many as they can remember. Then have several students stand, in pairs, at various points in the room and carry on loud conversations while you read a list of 20 new words to the remainder of the class. Ask students to again write down as many words as they can remember. Compare performance between the two trials. Mention to the students that, like the disruptive pairs of students, marijuana interferes with normal information transfer and memory. Students will identify the areas of the brain and structures responsible for these functions and will be reminded that marijuana alters neurotransmission in these areas. Students can also search the Internet and other sources to research the effects of marijuana on information transfer and memory and then prepare a brief report summarizing their findings.

OBJECTIVE

* **The student will learn more about the important role of the cerebellum.**

MARIJUANA ACTIVITY THREE

Explain that the cerebellum is involved in balance, coordination, and a variety of other regulatory functions. Marijuana affects the cerebellum, resulting in impairments in motor behavior. Students will search the Internet and other sources for more information about the role and function of the cerebellum and will make a list of ways in which damage to the cerebellum would affect their day-to-day behavior.

Opiates

BACKGROUND

Opiates are powerful drugs derived from the poppy plant that have been used for centuries to relieve pain. They include opium, heroin, morphine, and codeine. Even centuries after their discovery, opiates are still the most effective pain relievers available to physicians for treating pain. Although heroin has no medicinal use, other opiates, such as morphine and codeine, are used in the treatment of pain related to illnesses (for example, cancer) and medical and dental procedures. When used as directed by a physician, opiates are safe and generally do not produce addiction. But opiates also possess very strong reinforcing properties and can quickly trigger addiction when used improperly.

MECHANISM OF ACTION

Opiates elicit their powerful effects by activating opiate receptors that are widely distributed throughout the brain and body. Once an opiate reaches the brain, it quickly activates the opiate receptors that are found in many brain regions and produces an effect that correlates with the area of the brain involved. Two important effects produced by opiates, such as morphine, are pleasure (or reward) and pain relief. The brain itself also produces substances known as endorphins that activate the opiate receptors. Research indicates that endorphins are involved in many things, including respiration, nausea, vomiting, pain modulation, and hormonal regulation.

When opiates are prescribed by a physician for the treatment of pain and are taken in the prescribed dosage, they are safe and there is little chance of addiction. However, when opiates are abused and taken in excessive doses, addiction can result. Findings from animal research indicate that, like cocaine and other abused drugs, opiates can also activate the brain's reward system. When a person injects, sniffs, or orally ingests heroin (or morphine), the drug travels quickly to the brain through the bloodstream. Once in the brain, the heroin is rapidly converted to morphine, which then activates opiate receptors located throughout the brain, including within the reward system. (Note: Because of its chemical structure, heroin penetrates the brain more quickly than other opiates, which is probably why many addicts prefer heroin.) Within the reward system, the morphine activates opiate receptors in the VTA, nucleus accumbens, and cerebral cortex (refer to the Introduction for information on the reward system). Research suggests that stimulation of opiate receptors by morphine results in feelings of reward and activates the pleasure circuit by causing greater amounts of dopamine to be released within the nucleus accumbens. This causes an intense euphoria, or rush, that lasts only briefly and is followed by a few hours of a relaxed, contented state. This excessive release of dopamine and stimulation of the reward system can lead to addiction.

Opiates also act directly on the respiratory center in the brainstem, where they cause a slowdown in activity. This results in a decrease in breathing rate. Excessive amounts of an opiate, like heroin, can cause the respiratory centers to shut down breathing altogether. When someone overdoses on heroin, it is the action of heroin in the brainstem respiratory centers that can cause the person to stop breathing and die.

As mentioned earlier, the brain itself produces endorphins that have an important role in the relief or modulation of pain. Sometimes, though, particularly when pain is severe, the brain does not produce enough endorphins to provide pain relief. Fortunately, opiates, such as morphine are very powerful pain relieving

Feelings of pain are produced when specialized nerves are activated by trauma to some part of the body, either through injury or illness. These specialized nerves, which are located throughout the body, carry the pain message to the spinal cord. After reaching the spinal cord, the message is relayed to other neurons, some of which carry it to the brain. Opiates help to relieve pain by acting in both the spinal cord and brain. At the level of the spinal cord, opiates interfere with the transmission of the pain messages between neurons and therefore prevent them from reaching the brain. This blockade of pain messages protects a person from experiencing too much pain. This is known as analgesia.

Opiates also act in the brain to help

12

Opiates

There are several areas in the brain that are involved in interpreting pain messages and in subjective responses to pain. These brain regions are what allow a person to know he or she is experiencing pain and that it is unpleasant. Opiates also act in these brain regions, but they don't block the pain messages themselves. Rather, they change the subjective experience of the pain. This is why a person receiving morphine for pain may say that they still feel the pain but that it doesn't bother them anymore.

Although endorphins are not always adequate to relieve pain, they are very important for survival. If an animal or person is injured and needs to escape a harmful situation, it would be difficult to do so while experiencing severe pain. However, endorphins that are released immediately following an injury can provide enough pain relief to allow escape from a harmful situation. Later, when it is safe, the endorphin levels decrease and intense pain may be felt. This also is important for survival. If the endorphins continued to blunt the pain, it would be easy to ignore an injury and then not seek medical care.

There are several types of opiate receptors, including the delta, mu, and kappa receptors. Each of these three receptors is involved in controlling different brain functions. For example, opiates and endorphins are able to block pain signals by binding to the mu receptor site.

The powerful new technology of cloning has enabled scientists to copy the genes that make each of these receptors. This in turn is allowing researchers to conduct laboratory studies to better understand how opiates act in the brain and, more specifically, how opiates interact with each opiate receptor to produce their effects. This information may eventually lead to more effective treatments for pain and opiate addiction.

The following activities, when used along with the magazine on opiates, will help explain to students how these substances change the brain and the body.

13

Opiates

OBJECTIVE

* **The student will learn the way in which opiates alter the function of nerve cells.**

OPIATES ACTIVITY ONE

Remind students that long-term abuse of opiates, such as heroin, changes the way nerve cells in the brain work. These cells become so used to having the heroin present that they need it to work normally. This, in turn, leads to addiction. If opiates are taken away from dependent nerve cells, these cells become overactive. Eventually, they will work normally again, but in the meantime, they create a range of symptoms known as withdrawal. Have students create visual representations of normal nerve cells, dependent nerve cells, overactive nerve cells, and an opiate. Then have the students use these representations to develop, in comic art format, the process by which opiates change the normal functioning of neurons.

14

OBJECTIVE

* **The student will learn how opiates produce an analgesic effect.**

OPIATES ACTIVITY TWO

Note that opiates are powerful painkillers and are used medically for treatment of pain. When used properly for medical purposes, opiates do not produce an intense feeling of pleasure, and patients have little chance of becoming addicted. Have students search the Internet and other sources for information about pain, pain control, and the way opiates produce their analgesic effect and then prepare a brief summary report.

OBJECTIVE

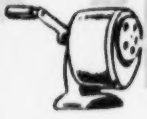
* **The student will become more familiar with neuroscience concepts and terminology associated with the effects of opiates on the brain.**

OPIATES ACTIVITY THREE

Students will solve a crossword puzzle which requires knowledge of the ways in which opiates affect brain anatomy and physiology. The puzzle and solution is included in the guide.

Opiates

CROSSWORD PUZZLE



ACROSS

1 Space between neurons

3 Copy genetic material to produce an identical cell

5 Opiates come from this plant

6 Feeling of euphoria

9 Controls breathing and heart rate

10 Pleasure neuro-transmitter

11 Pain relief

DOWN

1 Opiates act on the _____ cord and brain

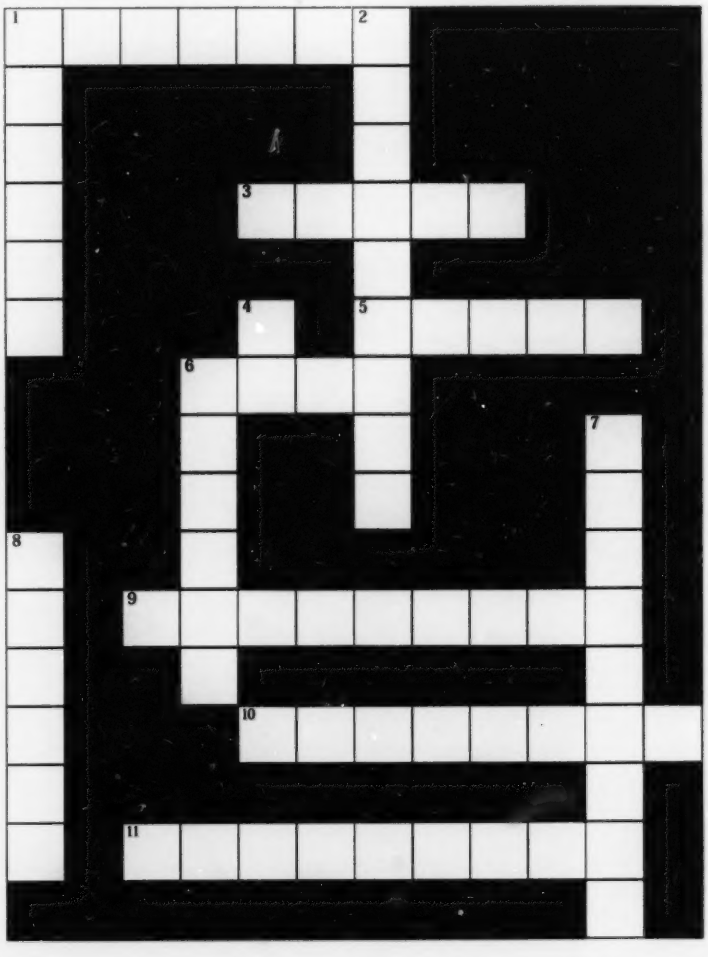
2 Pain reliever produced by brain

4 An opiate receptor

6 Another name for pleasure

7 Ventral _____ area

8 Powerful opiate



15

Opiates

CROSSWORD PUZZLE

SOLUTION

ACROSS

1 Space between neurons

3 Copy genetic material to produce an identical cell

5 Opiates come from this plant

6 Feeling of euphoria

9 Controls breathing and heart rate

10 Pleasure neuro-transmitter

11 Pain relief

DOWN

1 Opiates act on the _____ cord and brain

2 Pain reliever produced by brain

4 An opiate receptor

6 Another name for pleasure

7 Ventral _____ area

8 Powerful opiate

1 S	Y	N	A	P	S	2 E						
P						N						
I						D						
N				3 C	L	O	N	E				
A						R						
L				4 M		5 P	O	P	P	Y		
			6 R	U	S	H						
			E			I				7 T		
			W			N				E		
8 H			A							G		
E		9 B	R	A	I	N	S	T	E	M		
R			D							E		
O				10 D	O	P	A	M	I	N	E	
I										T		
N		11 A	N	A	L	G	E	S	I	A		
										L		

Inhalants

BACKGROUND

Most inhalants are common household products that give off mind-altering chemical fumes when sniffed. These common products include paint thinner, fingernail polish remover, glues, gasoline, cigarette lighter fluid, and nitrous oxide. They also include fluorinated hydrocarbons found in aerosols, such as whipped cream, hair and paint sprays, and computer cleaners. The chemical structure of the various types of inhalants is diverse, making it difficult to generalize about the effects of inhalants. It is known, however, that the vaporous fumes can change brain chemistry and may be permanently damaging to the brain and central nervous system.

Inhalant users are also at risk for Sudden Sniffing Death (SSD), which can occur when the inhaled fumes take the place of oxygen in the lungs and central nervous system. This basically causes the inhalant user to suffocate. Inhalants can also lead to death by disrupting the normal heart rhythm, which can lead to cardiac arrest. Use of inhalants can cause hepatitis, liver failure, and muscle weakness. Certain inhalants can also cause the body to produce fewer of all types of blood cells, which may result in life-threatening aplastic anemia.

Inhalants also alter the functioning of the nervous system. Some of these effects are transient and disappear after use is discontinued. But inhalant use can also lead to serious neurological problems, some of which are irreversible. For example, frequent long-term use of certain inhalants can cause a permanent change or malfunction of nerves in the back and legs, called polyneuropathy. Inhalants can also act directly in the brain to cause a variety of neurological problems. For instance, inhalants can cause abnormalities in brain areas that are involved in movement (for example, the cerebellum) and higher cognitive function (for example, the cerebral cortex).

MECHANISM OF ACTION

Inhalants enter the bloodstream quickly and are then distributed throughout the brain and body. They have direct effects on both the central nervous system (brain and spinal cord) and the peripheral nervous system (nerves throughout the body).

Using brain imaging techniques, such as magnetic resonance imaging (MRI), researchers have discovered that there are marked structural changes in the brains of chronic inhalant abusers. These changes include a reduction in size in certain brain areas, including the cerebral cortex, cerebellum, and brainstem. These changes may account for some of the neurological and behavioral symptoms that long-term inhalant abusers exhibit (for example, cognitive and motor difficulties). Some of these changes may be due to the effect inhalants have on myelin, the fatty tissue which insulates and protects axons and helps speed up nerve conduction. When inhalants enter the brain and body, they are particularly attracted to fatty tissues. Because myelin is a fat, it quickly absorbs inhalants, which can then damage or even destroy the myelin. The deterioration of myelin interferes with the rapid flow of messages from one nerve to another.

Inhalants can also have a profound effect on nerves that are located throughout the body. The polyneuropathy caused by some inhalants, as well as other neurological problems, may be due in part to the effect of the inhalants on the myelin sheath that covers axons throughout the body. In some cases, not only is the myelin destroyed, but the axons themselves degenerate.

The following activities, when used along with the magazine on inhalants, will help explain to students how these substances change the brain and the body.

Inhalants

OBJECTIVE

* **The student will learn the effects of inhalant use on brain-behavior relationships.**

INHALANTS ACTIVITY ONE

Introduce this activity by reminding students that inhalants can slow or stop nerve cell activity in some parts of the brain; for example, the frontal lobes (complex problem solving), cerebellum (movement and coordination), and hippocampus (memory). Students will break into small groups and contribute in a round-robin fashion to a story about a fictional student who uses inhalants. The students should be encouraged to include problems (symptoms) in the description that would be associated with inhalant use, as well as other symptoms that would not. These stories can then be shared (either in oral or written form) with the rest of the class, who will be required to identify the inhalant-related behavioral components and then describe the brain areas that are involved in these behaviors. Students will then search the Internet and other sources to obtain information about the way in which activity in the frontal lobes, cerebellum, and hippocampus influences behavior, and prepare a report summarizing their findings.

OBJECTIVE

* **The student will understand the effect of inhalants on brain structures, physiology, and behavior.**

INHALANTS ACTIVITY TWO

Review the regions of the brain and structures affected by inhaling solvents, gases, and nitrites. Then divide the class into groups of 4-6, and have each group write a rap music video about the effects of inhalants on brain areas and structures, as well as brain-behavior relationships. When the songs are finished, have each group perform their music video.

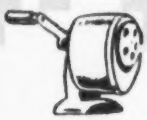
OBJECTIVE

* **The student will become more familiar with the neuroscience concepts and terminology associated with the effects of inhalants on the brain and body.**

INHALANTS ACTIVITY THREE

The students will complete the Inhalant Word Find, and the teacher will then review the words and have the students discuss how the terms relate to inhalant use. A copy of the Word Find and the Word Find Solution is included in the guide.

Inhalants



WORD SEARCH

A	A	L	A	D	G	Y	M	A	N	Y
Z	U	X	I	I	M	P	A	M	A	V
S	D	B	F	N	Z	J	L	R	C	P
H	J	P	W	H	M	G	R	O	E	S
B	N	O	X	A	I	S	O	P	R	B
A	F	L	J	L	K	O	W	A	E	W
T	E	Y	K	A	I	B	Y	V	B	E
D	V	N	K	N	D	V	B	S	E	Q
C	S	E	G	T	N	N	E	U	L	G
B	G	U	K	C	E	L	L	R	L	S
T	X	R	F	L	Y	P	L	M	U	X
I	E	O	R	F	U	M	E	S	M	F
D	T	P	F	W	O	K	R	Y	O	N
J	R	A	X	F	A	C	E	C	P	R
C	O	T	F	Y	I	L	A	Z	U	Y
T	C	H	L	X	I	N	B	T	D	I
E	H	Y	H	N	X	V	S	T	E	C
U	E	O	R	L	N	Q	O	H	A	G

19

Amygdala
Axon
Cell
Cerebellum
Cortex
Fumes
Glue
Inhalant
Kidney
Liver
Myelin
Polyneuropathy
Sniff
Vapor

Inhalants

WORD SEARCH

SOLUTION

A	A	L	A	D	G	Y	M	A	N	Y
Z	U	X	I	I	M	P	A	M	A	V
S	D	B	F	N	Z	J	L	R	C	P
H	J	P	W	H	M	G	R	O	E	S
B	N	O	X	A	I	S	O	P	R	B
A	F	L	J	L	K	O	W	A	E	W
T	E	Y	K	A	I	B	Y	V	B	E
D	V	N	K	N	D	V	B	S	E	Q
C	S	E	G	T	N	N	E	U	L	G
B	G	U	K	C	E	L	L	R	L	S
T	X	R	F	L	Y	P	L	M	U	X
I	E	O	R	F	U	M	E	S	M	F
D	T	P	F	W	O	K	R	Y	O	N
J	R	A	X	F	A	C	E	C	P	R
C	O	T	F	Y	I	L	A	Z	U	Y
T	C	H	L	X	I	N	B	T	D	I
E	H	Y	H	N	X	V	S	T	E	C
U	E	O	R	L	N	Q	O	H	A	G

20

Amygdala
Axon
Cell
Cerebellum
Cortex
Fumes
Glue
Inhalant
Kidney
Liver
Myelin
Polyneuropathy
Sniff
Vapor

Hallucinogens

BACKGROUND

Hallucinogens are drugs which cause altered states of perception and feeling and which can produce flashbacks. They include natural substances, such as mescaline and psilocybin that come from plants (cactus and mushrooms), and chemically manufactured ones, such as LSD and MDMA (ecstasy). LSD is manufactured from lysergic acid, which is found in ergot, a fungus that grows on rye and other grains. MDMA is a synthetic mind-altering drug with hallucinogenic properties. Although not a true hallucinogen in the pharmacological sense, PCP causes many of the same effects as hallucinogens and so is often included with this group of drugs. Hallucinogens have powerful mind-altering effects. They can change how the brain perceives time, everyday reality, and the surrounding environment. They affect regions and structures in the brain that are responsible for coordination, thought processes, hearing, and sight. They can cause people who use them to hear voices, see images, and feel sensations that do not exist. Researchers are not certain that brain chemistry permanently changes from hallucinogen use, but some people who use them appear to develop chronic mental disorders. PCP and MDMA are both addicting; whereas LSD, psilocybin, and mescaline are not.

Research has provided many clues about how hallucinogens act in the brain to cause their powerful effects. However, because there are different types of hallucinogens and their effects are so widespread, there is still much that is unknown. The following paragraphs describe some of what is known about this diverse group of drugs.

MECHANISM OF ACTION

LSD binds to and activates a specific receptor for the neurotransmitter serotonin. Normally, serotonin binds to and activates its receptors and then is taken back up into the neuron that released it. In contrast, LSD binds very tightly to the serotonin receptor, causing a greater than normal activation of the receptor. Because serotonin has a role in many of the brain's functions, activation of its receptors by LSD produces widespread effects, including rapid emotional swings, and altered perceptions, and if taken in a large enough dose, delusions and visual hallucinations.

MDMA, which is similar in structure to methamphetamine, causes serotonin to be released from neurons in greater amounts than normal. Once released, this serotonin can excessively activate serotonin receptors. Scientists have also shown that MDMA causes excess dopamine to be released from dopamine-containing neurons. Particularly alarming is research in animals that has demonstrated that MDMA can damage and destroy serotonin containing neurons. MDMA can cause hallucinations, confusion, depression, sleep problems, drug craving, severe anxiety, and paranoia.

PCP, which is not a true hallucinogen, can affect many neurotransmitter systems. It interferes with the functioning of the neurotransmitter glutamate, which is found in neurons throughout the brain. Like many other drugs, it also causes dopamine to be released from neurons into the synapse. At low to moderate doses, PCP causes altered perception of body image, but rarely produces visual hallucinations. PCP can also cause effects that mimic the primary symptoms of schizophrenia, such as delusions and mental turmoil. People who use PCP for long periods of time have memory loss and speech difficulties.

The following activities, when used along with the magazine on hallucinogens, will help explain to students how these substances change the brain and the body.

Hallucinogens

OBJECTIVE

* **The student will learn how hallucinogens cause visual misperception and hallucinations.**

HALLUCINOGENS ACTIVITY ONE

Have students draw a bull's-eye onto a sheet of unruled white paper. Make a small "X" at the center of another sheet of paper. Now, have the students stare at the bull's-eye for about 20 seconds and then quickly shift their focus to the "X." Students will find that an after-image of the bull's-eye will appear. Explain that after-images are a class of optical illusions, which have some similarity to hallucinations. Have students search the Internet and other sources for information about drug-induced hallucinations and prepare a report summarizing their findings.

OBJECTIVE

* **The student will learn that hallucinogens cause other sensory misperceptions.**

HALLUCINOGENS ACTIVITY TWO

Fill one bowl with warm water, another with cold water, and a third with water at room temperature. First, have the students place the fingers of one hand in the warm water. Wait 60 seconds. Then have them place their fingers in the room temperature water and describe the temperature of the water (feels cool). Then have the students place their fingers of the other hand in the cold water. Wait 60 seconds. Then have them place their fingers in the room temperature water and describe the temperature of the water (feels hot). Remind students that hallucinogens can affect the way we perceive reality.

OBJECTIVE

* **The student will learn vocabulary and facts associated with hallucinogens.**

HALLUCINOGENS ACTIVITY THREE

Instruct the students to complete the Hallucinogen Word Puzzle. The puzzle and solution to the puzzle are included in the guide.

WORD PUZZLE

Answer each question, below then correctly arrange the boxed letters to solve the riddle at the bottom of the page.

1 ___ ___ ___ ___ ___ ___ ___ ___ ___
LSD binds tightly to and activates the receptor for what neurotransmitter?

2 ___ ___ ___ ___ ___ ___ ___ ___ ___
What drug comes from a cactus plant?

3 ___ ___ ___ ___ ___ ___ ___
What is another name for MDMA?

4 ___ ___ ___ ___ ___ ___ ___ ___ ___
Neurotransmitters attach to what molecules in the cell membrane?

5 ___ ___ ___ ___
What is another name for LSD?

6 ___ ___ ___ ___ ___ ___ ___ ___ ___
Changes in what brain structure affect breathing and heart rate?

___ ___ ___ ___ ___ ___ ___ ___ ___

What might result if you use either

SOLUTION

WORD PUZZLE

Answer each question, below then correctly arrange the boxed letters to solve the riddle at the bottom of the page.

1 S E R O **T** O N **I** N
LSD binds tightly to and activates the receptor for what neurotransmitter?

2 M E S C **A** L I N E
What drug comes from a cactus plant?

3 E C S T **A** C Y
What is another name for MDMA?

4 **R** E C E **P** T O R S
Neurotransmitters attach to what molecules in the cell membrane?

5 A C I **D**
What is another name for LSD?

6 **B** R A I N S T E M
Changes in what brain structure affect breathing and heart rate?

A **B A D** **T R I P**

What might result if you use either

Steroids

BACKGROUND

Anabolic steroids are chemicals that are similar to the male sex hormone testosterone and are used by an increasing number of young people to enhance their muscle size. While anabolic steroids are quite successful at building muscle, they can damage many body organs, including the liver, kidneys, and heart. They may also trigger dependency in users, particularly when taken in the large doses that have been known to be used by many bodybuilders and athletes.

MECHANISM OF ACTION

Anabolic steroids are taken either orally in pill form or by injection. After steroids enter the bloodstream, they are distributed to organs (including muscle) throughout the body. After reaching these organs, the steroids surround individual cells in the organ and then pass through the cell membranes to enter the cytoplasm of the cells. Once in the cytoplasm, the steroids bind to specific receptors and then enter the nucleus of the cells. The steroid-receptor complex is then able to alter the functioning of the genetic material and stimulate the production of new proteins. It is these proteins that carry out the effects of the steroids. The types of proteins and the effects vary depending on the specific organ involved. Steroids are able to alter the functioning of many organs, including the liver, kidneys, heart, and brain. They can also have a profound effect on reproductive organs and hormones.

Many of the effects of steroids are brought about through their actions in the brain. Once steroids enter the brain, they are distributed to many regions, including the hypothalamus and limbic system. When a person takes steroids, the functioning of neurons in both of these areas is altered, resulting in a change in the types of messages that are transmitted by the neurons. Since the hypothalamus has a major role in maintaining normal hormone levels, disrupting its normal functioning also disrupts the body's hormones. This can result in many problems, including a reduction in normal testosterone production in males and loss of the monthly period in females.

Similarly, steroids can also disrupt the functioning of neurons in the limbic system. The limbic system is involved in many things, including learning, memory, and regulation of moods. Studies in animals have shown that steroids can impair learning and memory. They can also promote overly-aggressive behavior and mood swings. People who take anabolic steroids can exhibit violent behavior, impairment of judgment, and even psychotic symptoms.

Other effects of taking anabolic steroids include changes in male and female sexual characteristics, stunted growth, and an increase in the amount of harmful cholesterol in the body. Anabolic steroids can also influence the growth of facial and chest hair and a cause a deepening of the voice.

The following activities, when used along with the magazine on anabolic steroids, will help explain to students how these substances change the brain and the body.

Steroids

OBJECTIVE

* **The student will understand that steroids have a direct effect on the limbic system, which has a large role in the expression of emotions.**

STEROIDS ACTIVITY ONE

Ask students to imagine a time where they experienced, very suddenly, either intense rage or aggressiveness. Those who would like to can share some of these experiences with the class. Reinforce that the limbic system was likely involved in these reactions and that steroid use directly increases the likelihood of such episodes. Mention that neuroscientists have long known about the important role the limbic system plays in emotions and have conducted animal research in which stimulating certain limbic system structures produces a rage reaction in a normally docile animal, while stimulating other structures makes a normally vicious animal calm and relaxed. Have students conduct research using the Internet and other sources to learn more about the role of the limbic system.

26

OBJECTIVE

* **The student will learn more about the functions of key neurotransmitters including serotonin, glutamate, dopamine, and acetylcholine.**

STEROIDS ACTIVITY TWO

Indicate that steroids affect the function of several neurotransmitters, adding that each neurotransmitter communicates different types of messages. For example, glutamate communicates excitement, acetylcholine tells the heart to beat slower and commands memory circuits to store or remember thoughts, serotonin controls emotions and mood, and dopamine affects feelings of pleasure. Students will select a neurotransmitter and search the Internet and other sources for additional information. They will prepare a brief report summarizing their findings and create a comic art rendition of their neurotransmitter.

OBJECTIVE

* **The student will learn about the performance enhancing effects of steroids, and the medical risk factors.**

STEROIDS ACTIVITY THREE

Remind students that despite their dangerous side effects, anabolic steroids are used by some high school, college, and professional athletes to give them the "edge" they feel they need to out perform the competition. Discuss with the students the short- and long-term dangers associated with the use of steroids for enhancing performance. A useful example for this discussion might be Lyle Alzado, a former professional football star who died from cancer attributed to steroid use.

BACKGROUND

Stimulant drugs such as cocaine, "crack," amphetamines, and caffeine are substances that speed up activity in the brain and spinal cord. This, in turn, can cause the heart to beat faster and blood pressure and metabolism to increase. Stimulants often influence a person to be more talkative and anxious and to experience feelings of exhilaration.

Use of cocaine and other stimulants can cause someone's heart to beat abnormally fast and at an unsteady rate. Use of these drugs also narrows blood vessels, reducing the flow of blood and oxygen to the heart, which results in "starving" the heart muscle. Even professional athletes whose bodies are well-conditioned have succumbed to cocaine's ability to cause heart failure. Researchers currently have no way to detect who may be more susceptible to these effects.

MECHANISM OF ACTION

Cocaine acts on the pleasure circuit to prevent reabsorption of the neurotransmitter dopamine after its release from nerve cells. Normally, neurons that are part of the pleasure circuit release dopamine, which then crosses the synapse to stimulate another neuron in the pleasure circuit. Once this has been accomplished, the dopamine is picked up by a transporter molecule and carried back into the original neuron. However, because cocaine binds to the dopamine transporter molecule, it prevents the reabsorption of dopamine. This causes a build up of dopamine in the synapse, which results in strong feelings of pleasure and even euphoria. The excess dopamine that accumulates in the synapse causes the neurons that have dopamine receptors to decrease the number of receptors they make. This is called down regulation. When cocaine is no longer taken and dopamine levels return to their normal (i.e., lower) concentration, the smaller number of dopamine receptors that are available for the neurotransmitter to bind to is insufficient to fully activate nerve cells. This results in a drug "craving," which is a way of telling the addict to get the level of dopamine back up by taking cocaine. Cocaine also binds to the transporters for other neurotransmitters, including serotonin and norepinephrine, and blocks their re-uptake. Scientists are still unsure about the effects of cocaine's interaction with these other neurotransmitters.

Cocaine has also been found to specifically affect the prefrontal cortex and amygdala, which are involved in aspects of memory and learning. The amygdala has been linked to emotional aspects of memory. Researchers believe that a neural network involving these brain regions reacts to environmental cues and activates memories, and this triggers biochemical changes that result in cocaine craving.

27

Stimulants

Amphetamines, such as methamphetamine, also act on the pleasure circuit by altering the levels of certain neurotransmitters present in the synapse, but the mechanism is different from that of cocaine. Chemically, methamphetamine is closely related to amphetamine, but it has greater effects on the brain. Methamphetamine is also chemically similar to dopamine and another neurotransmitter, norepinephrine. It produces its effects by causing dopamine and norepinephrine to be released into the synapse in several areas of the brain, including the nucleus accumbens, prefrontal cortex, and the striatum, a brain area involved in movement. Specifically, methamphetamine enters nerve terminals by passing directly through nerve cell membranes. It is also carried into the nerve terminals by transporter molecules that normally carry dopamine or norepinephrine from the synapse back into the nerve terminal. Once in the nerve terminal, methamphetamine enters dopamine and norepinephrine containing vesicles and causes the release of these neurotransmitters. Excess dopamine and norepinephrine would normally be chewed up by enzymes in the cell, however, methamphetamine blocks this breakdown. The excess neurotransmitters are then carried by transporter molecules out of the neuron and into the synapse. Once in the synapse, the high concentrations of dopamine causes feelings of pleasure and euphoria. The excess norepinephrine may be responsible for the alertness and anti-fatigue effects of methamphetamine.

Methamphetamine can also affect the brain in other ways. For example it can cause cerebral edema, brain hemorrhage, paranoia, and hallucinations. Some of methamphetamine's effects on the brain may be long-lasting and even permanent. Research with laboratory animals has demonstrated that exposure to a single, high-dose of methamphetamine or prolonged exposure at low doses destroys up to fifty percent of the dopamine-producing neurons in certain parts of the brain. Studies are currently underway to study the long-term effects of chronic methamphetamine abuse in humans. Although the damage of chronic methamphetamine abuse may not be immediately apparent in humans, scientists believe that the progressive decrease in numbers of dopamine-producing neurons may lead to symptoms of Parkinson's disease.

Methamphetamine also has widespread effects on other parts of the body. It can cause high blood pressure, arrhythmias, chest pain, shortness of breath, nausea, vomiting, and diarrhea. It can also increase body temperature which can be lethal in overdose situations.

The following activities, when used along with the magazine on stimulants, will help explain to students how these substances change the brain and the body.

OBJECTIVE

* **The student will learn that cocaine affects neurotransmission in the mesolimbic dopamine system, sometimes referred to as the pleasure center.**

COCAINE ACTIVITY ONE

Remind students that cocaine activates the brain's pleasure center, which involves the brainstem, limbic system, and frontal cortex. Students will then produce colorful diagrams of the system, labeling important parts, and provide a brief written description of the different structures.

OBJECTIVES

* **The student will learn the way in which dopamine is related to the sensation of pleasure.**
* **The student will learn how stimulants interfere with dopamine re-uptake.**

COCAINE ACTIVITY TWO

Describe how cocaine ultimately reduces pleasure by interfering with dopamine re-uptake. Students will be assigned to groups and will first script and then act-out this process. They will then perform their skits with students assuming roles such as neurons, cocaine, transporters, receptors, dopamine, pleasure, and addiction.

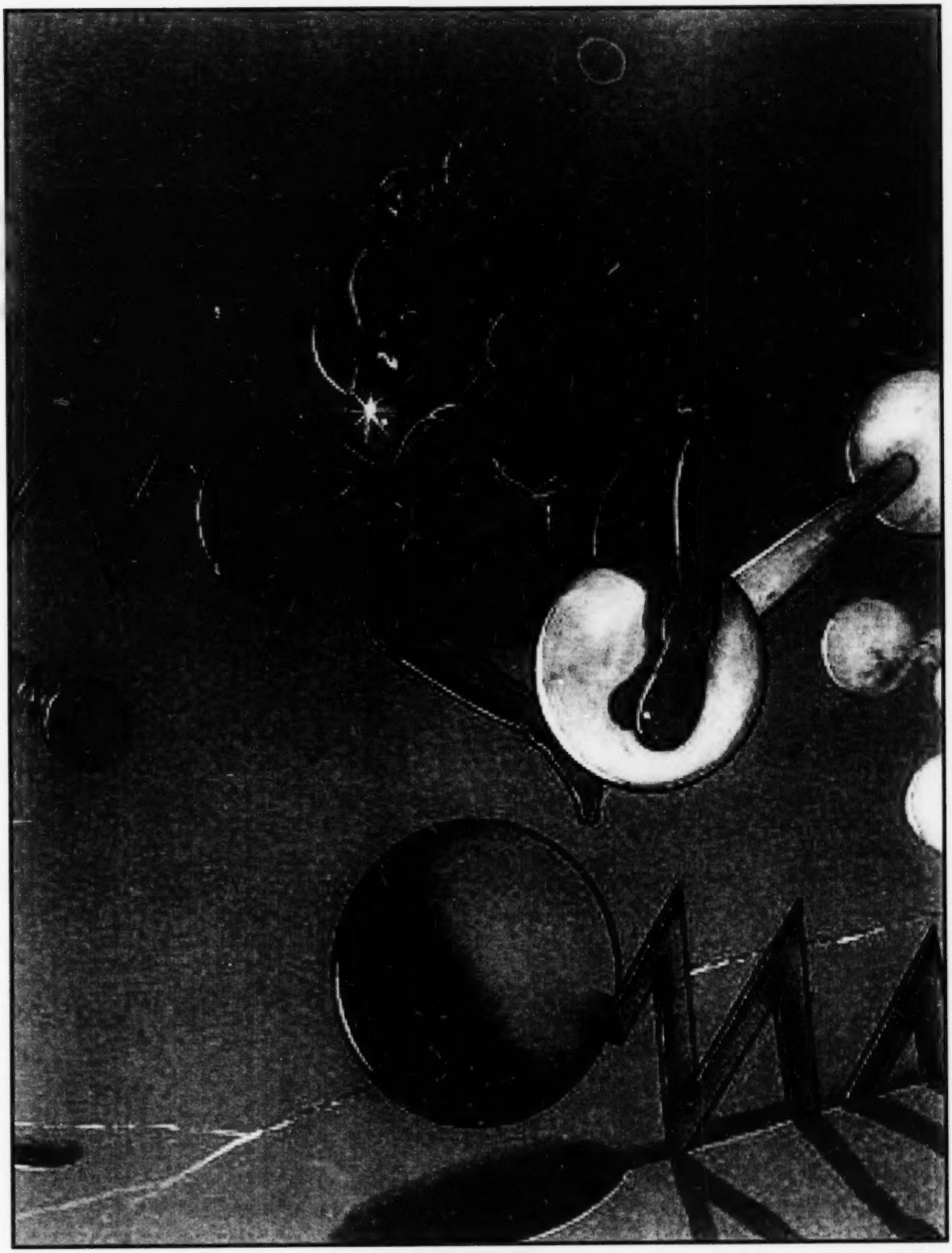
29

OBJECTIVE

* **The student will learn and share interesting and unusual information about the effects of cocaine, amphetamines, and caffeine on the brain and behavior.**

COCAINE ACTIVITY THREE

Divide the students into three groups (cocaine, amphetamines, and caffeine), and assign each group the task of researching their assigned drug in order to develop a "Did You Know" poster for each type of drug. Encourage each group to discover some "surprising" information to include on their poster, and ask that each poster contain a minimum of 10 new and/or unusual facts. Students will use the local public library, the Internet, other multimedia materials, and any other sources to obtain this information. They will then work together to develop the graphics and text. Display the finished posters.



BACKGROUND

Tobacco, which comes primarily from the plant nicotiana tabacum, has been used for centuries. It can be smoked, chewed, or sniffed. The first description of addiction to tobacco is contained in a report from the New World in which Spanish soldiers said that they could not stop smoking.

When nicotine was isolated from tobacco leaves in 1828, scientists began studying its effects in the brain and body. This research eventually showed that, although tobacco contains thousands of chemicals, the main ingredient that acts in the brain and produces addiction is nicotine. More recent research has shown that the addiction produced by nicotine is extremely powerful and is at least as strong as addictions to other drugs such as heroin and cocaine.

Some of the effects of nicotine include changes in respiration and blood pressure, constriction of arteries, and increased alertness. Many of these effects are produced through its action on both the central and peripheral nervous system.

MECHANISM OF ACTION

Nicotine readily enters the body. When tobacco is smoked, nicotine enters the bloodstream through the lungs. When it is sniffed or chewed, nicotine passes through the mucous membranes of the mouth or nose to enter the bloodstream. Nicotine can also enter the bloodstream by passing through the skin. Regardless of how nicotine reaches the bloodstream, once there, it is distributed throughout the body and brain where it activates specific types of receptors known as cholinergic receptors.

Cholinergic receptors are present in many brain structures, as well as in muscles, adrenal glands, the heart, and other body organs. These receptors are normally activated by the neurotransmitter acetylcholine, which is produced in the brain, and by neurons in the peripheral nervous system. Acetylcholine and its receptors are involved in many activities, including respiration, maintenance of heart rate, memory, alertness, and muscle movement.

Because the chemical structure of nicotine is similar to that of acetylcholine's, it is also able to activate cholinergic receptors. But unlike acetylcholine, when nicotine enters the brain and activates cholinergic receptors, it can disrupt the normal functioning of the brain.

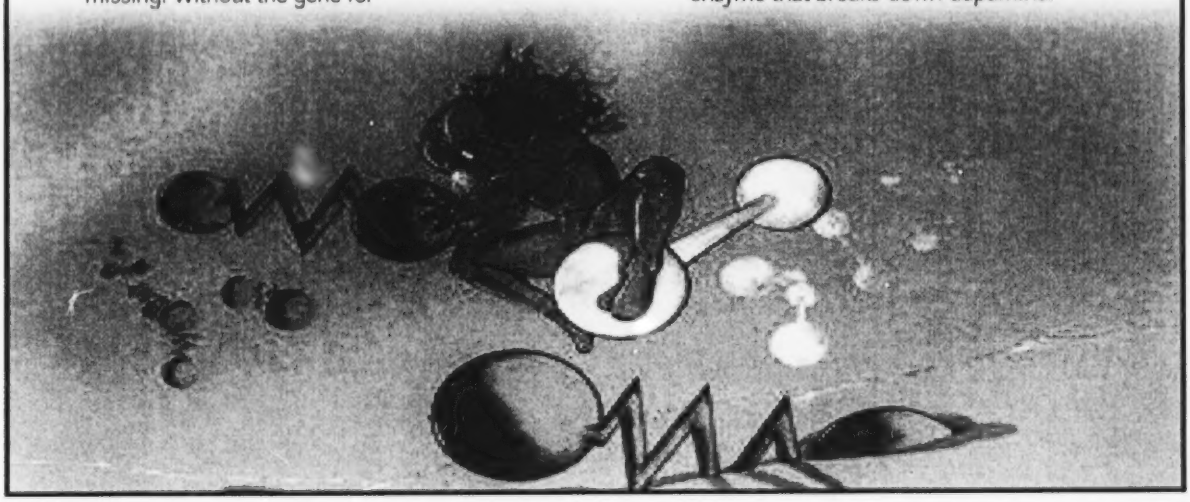
Regular nicotine use causes changes in both the number of cholinergic receptors and the sensitivity of these receptors to nicotine and acetylcholine. Some of these changes may be responsible for the development of tolerance to nicotine. Once tolerance has developed, a nicotine user must regularly supply the brain with nicotine in order to maintain normal brain functioning. If nicotine levels drop, the nicotine user will begin to feel uncomfortable withdrawal symptoms.

Nicotine

Recently, research has shown that nicotine also stimulates the release of the neurotransmitter dopamine in the brain's pleasure circuit. Using microdialysis, a technique that allows minute quantities of neurotransmitters to be measured in precise brain areas, researchers have discovered that nicotine causes an increase in the release of dopamine in the nucleus accumbens. This release of dopamine is similar to that seen for other drugs of abuse, such as heroin and cocaine, and is thought to underlie the pleasurable sensations experienced by many smokers.

Other research is providing even more clues as to how nicotine may exert its effects in the brain. Cholinergic receptors are relatively large structures that consist of several components known as subunits. One of these subunits, the ß (beta) subunit, has recently been implicated as having a role in nicotine addiction. Using highly sophisticated bioengineering technologies, scientists were able to produce a new strain of mice in which the gene that produces the ß subunit was missing. Without the gene for the ß subunit, these mice, which are known as "knockout" mice because a particular gene has been knocked out, were unable to produce any ß subunits. What researchers found when they examined these knockout mice was that in contrast to mice who had an intact receptor, mice without the ß subunit would not self-administer nicotine. These studies demonstrate that the ß subunit plays a critical role in mediating the pleasurable effects of nicotine. The results also provide scientists with valuable new information about how nicotine acts in the brain, information that may eventually lead to better treatments for nicotine addiction.

However nicotine may not be the only psychoactive ingredient in tobacco. Using advanced brain imaging technology, it is possible to actually see what tobacco smoking is doing to the brain of an awake and behaving human being. Using one type of brain imaging, positron emission tomography (PET), scientists discovered that cigarette smoking causes a dramatic decrease in the levels of an important enzyme that breaks down dopamine.



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Nicotine

The decrease in this enzyme, known as monoamine-oxidase-A (MAO-A), results in an increase in dopamine levels. Importantly, this particular effect is not caused by nicotine but by some additional, unknown compound in cigarette smoke. Nicotine itself does not alter MAO-A levels; it affects dopamine through other mechanisms. Thus, there may be multiple routes by which smoking alters the neurotransmitter dopamine to ultimately produce feelings of pleasure and reward.

That nicotine is a highly addictive drug can clearly be seen when one considers the vast number of people who continue to use tobacco products despite their well known harmful and even lethal effects. In fact, at least 90% of smokers would like to quit, but each year fewer than 10% who try are actually successful. But, while nicotine may produce addiction to tobacco products, it is the thousands of other chemicals in tobacco that are responsible for its many adverse health effects.

Smoking either cigarettes or cigars can cause respiratory problems, lung cancer, emphysema, heart problems, and peripheral vascular disease. In fact, smoking is the largest preventable cause of premature death and disability. Cigarette smoking kills at least 400,000 people in the United States each year and makes countless others ill, including those who are exposed to secondhand smoke. The use of smokeless tobacco is also associated with serious health problems.

Chewing tobacco can cause cancers of the oral cavity, pharynx, larynx, and esophagus. It also causes damage to gums that may lead to the loss of teeth. Although popular among sports figures, smokeless tobacco can also reduce physical performance.

33

Nicotine

OBJECTIVE

* **The student will become more familiar with the neuroscience concepts and terminology associated with the effects of nicotine and tobacco products on the brain and body.**

NICOTINE ACTIVITY ONE

The students will complete the Nicotine Word Find, and the teacher will then review the words and have the students discuss how the terms relate to tobacco use. A copy of the Word Find and Word Find Solution is included in the guide.

OBJECTIVE

* **The student will understand that nicotine is a highly addictive drug and that once someone has become addicted, it is very difficult to stop smoking, even in the face of serious health consequences.**

34

NICOTINE ACTIVITY TWO

The students will call local hospitals to obtain the names of physicians who provide treatment to people trying to stop their use of tobacco products. The students will then compose a letter to one or more of these physicians inviting them to come and speak to the class on the difficulties associated with quitting smoking or the use of other tobacco products. Prior to the visit by the physician, the students will prepare a list of questions that they would like to ask. These questions might include the following: 1) How many people succeed the first or even second time they try to stop smoking? 2) How many people try repeatedly to quit smoking without success? 3) Do people still smoke even when they have a life-threatening illness, such as heart disease or lung cancer?

OBJECTIVE

* **The student will learn that cigarette smoke contains molecules that are deposited along the entire respiratory tract, including the lungs. These molecules not only turn the lungs and other parts of the respiratory system black, but they also cause cancers and other respiratory illnesses.**

NICOTINE ACTIVITY THREE

The students will conduct the following experiment:

Materials needed: cigarette, transparent plastic syringe, cotton balls, matches or lighter

Fill the syringe with the cotton balls. Insert the end of the syringe onto the filter of the cigarette. Light the cigarette and pull back the plunger to draw smoke into the barrel of the syringe. Have the students watch the cotton balls turn black as the smoke particles are deposited. Discuss with the students what they have observed. Students might consider what the effects of smoking several cigarettes a day for many years would have on the lungs if only one cigarette can turn a cotton ball black.

Nicotine

WORD SEARCH

A	Z	W	S	A	M	E	S	Y	H	P	M	E
R	O	T	P	E	C	E	R	Q	Y	I	N	P
R	E	S	L	O	L	J	G	T	R	I	E	N
B	N	I	A	R	B	U	O	D	L	P	U	M
L	R	Z	W	A	R	T	M	O	O	T	R	K
O	X	Q	A	D	E	I	H	P	R	Z	O	R
O	Q	A	R	W	O	C	C	A	B	O	T	N
D	S	E	D	E	L	D	G	M	R	F	R	O
S	Y	G	H	Y	U	I	J	I	K	I	A	I
T	X	P	T	C	C	L	V	N	J	B	N	T
R	N	E	I	M	A	R	T	E	Y	I	S	C
E	C	Q	W	O	Z	C	D	O	P	M	M	I
A	D	D	R	Y	C	T	A	R	E	N	I	D
M	O	T	K	Z	Q	P	O	N	A	T	T	D
N	E	T	T	E	R	A	G	I	C	W	T	A
G	E	U	N	I	C	O	T	I	N	E	E	L
A	L	S	G	N	I	K	O	M	S	I	R	R

35

EMPHYSEMA
NEUROTRANSMITTER
CIGAR
DOPAMINE
ADDICTION
REWARD
SMOKING
WITHDRAWAL
CIGARETTE
CANCER
DRUG
ACETYLCHOLINE
BRAIN
BLOODSTREAM
RECEPTOR
NICOTINE
TOBACCO

Nicotine

WORD SEARCH

SOLUTION

A	Z	W	S	A	M	E	S	Y	H	P	M	E
R	O	T	P	E	C	E	R	Q	Y	I	N	P
R	E	S	L	O	L	J	G	T	R	I	E	N
B	N	I	A	R	B	U	O	D	L	P	U	M
L	R	Z	W	A	R	T	M	O	O	T	R	K
O	X	Q	A	D	E	I	H	P	R	Z	O	R
O	Q	A	R	W	O	C	C	A	B	O	T	N
D	S	E	D	E	L	D	G	M	R	F	R	O
S	Y	G	H	Y	U	I	J	I	K	I	A	I
T	X	P	T	C	C	L	V	N	J	B	N	T
R	N	E	I	M	A	R	T	E	Y	I	S	C
E	C	Q	W	O	Z	C	D	O	P	M	M	I
A	D	D	R	Y	C	T	A	R	E	N	I	D
M	O	T	K	Z	Q	P	O	N	A	T	T	D
N	E	T	T	E	R	A	G	I	C	W	T	A
G	E	U	N	I	C	O	T	I	N	E	E	L
A	L	S	G	N	I	K	O	M	S	I	R	R

EMPHYSEMA
NEUROTRANSMITTER
CIGAR
DOPAMINE
ADDICTION
REWARD
SMOKING
WITHDRAWAL
CIGARETTE
CANCER
DRUG
ACETYLCHOLINE
BRAIN
BLOODSTREAM
RECEPTOR
NICOTINE
TOBACCO

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OBJECTIVES

- **The student will learn the names of the lobes, cortical areas, and structures in the brain.**
- **The student will learn the specific brain areas and structures affected by drug use.**

UNIFYING ACTIVITY

Students will use reference materials to create three brain maps: one which shows the different regions of the brain, one which shows the areas within the cortex, and one which displays different brain structures. For all of the drugs discussed, students will "mark" their maps (for example, using stickers or colored markers) to specify the areas affected by substance use. [Note: If materials such as molding clay or plaster are available, have groups of students also create three-dimensional brain models, and use small, separate strands of Christmas lights to "mark" the areas affected by drug use.]

38

Resources

National Institute on Drug Abuse
301-443-6245
http://www.nida.nih.org

National Clearinghouse for Alcohol and Drug Information
1-800-729-6686 or 1-800-487-4889 (TDD)
http://www.health.org

Office of Science Education
National Institutes of Health
301-402-2828

Society for Neuroscience
Education Program
202-462-6688
http://www.sfn.org

Internet Sites

National Institute on Drug Abuse
http://www.nida.nih.gov
This site contains information on drugs of abuse, NIDA publications and communications, agency events, and links to other drug-related Internet sites.

National Families in Action Online
http://www.emory.edu
This site includes the latest scientific information about the effects of drugs on the brain and body, and allows the visitor to ask neuroscience experts questions about drugs.

National Clearinghouse for Alcohol and Drug Information
http://www.health.org
This site includes information on publications, calendars, and related Internet sites, as well as "For Kids Only" materials including games, "really cool" links, and an "Are you Curious? Ask US!" page that allows visitors to ask experts questions about drugs.

Snapshots of Medicine and Health
National Institutes of Health
http://ohrm.od.nih.gov
This site includes information about people involved in biomedical sciences, the latest developments in biomedicine, interactive learning exercises, and links to other sites that focus on biomedicine, science, and education.

Neuroscience for Kids
http://weber.u.washington.edu/~chudler/neuroscience.html
This site includes answers to commonly-asked questions about the brain and neuroscience, with information on brain and spinal cord anatomy and physiology, neurotransmission, and the effects of specific drugs on the nervous system.

Dana Alliance for Brain Initiatives
http://www.dana.org/brainweb
This site includes resources for people interested in brain diseases and disorders, with specific sections devoted to alcohol and drug abuse.

Society for Neuroscience Brain Briefings
http://www.sfn.org/briefings
This site provides access to Society for Neuroscience publications covering topics such as addiction, opiate receptors, and the effects of various drugs on the brain and behavior.

MedWeb
http://www.gen.emory.edu/medweb
This site includes extensive lists of Internet resources and links to Internet sites devoted to neuroscience and drugs of abuse.

Cornell University Medical College
http://neuro.med.cornell.edu
This site includes extensive lists of Internet resources and links to Internet sites devoted to neuroscience and drugs of abuse.

Neurosciences on the Internet
http://www.neuroguide.com
This site includes information on basic neurosciences, including recent journal articles that discuss drugs of abuse.

Bill Nye the Science Guy (Episode 34)
http://nyelabs.kcts.org
This site presents information from Episode 34 – The Brain. It includes brain facts and hands-on activities.

Wisconsin/Michigan State Brain Collections
http://www.neurophys.wisc.edu
This site includes a visual tour of photos and brain sections of mammalian brains, with related information on brain anatomy, brain functions, and neuroanatomy.

Reading List

Brain Facts: A primer on the Brain and Nervous System, Society for Neuroscience, 1993.

How your Brain Works, by Anne D. Novitt-Morino, M.D., Ziff-Davis Press, 1995.

Explorations in Neuroscience for Children and Adults, Baylor College of Medicine, WOW Publications, Inc., 1997.

40

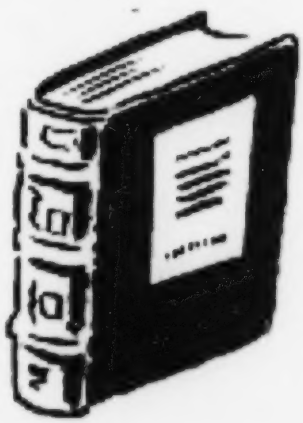


Figure 1

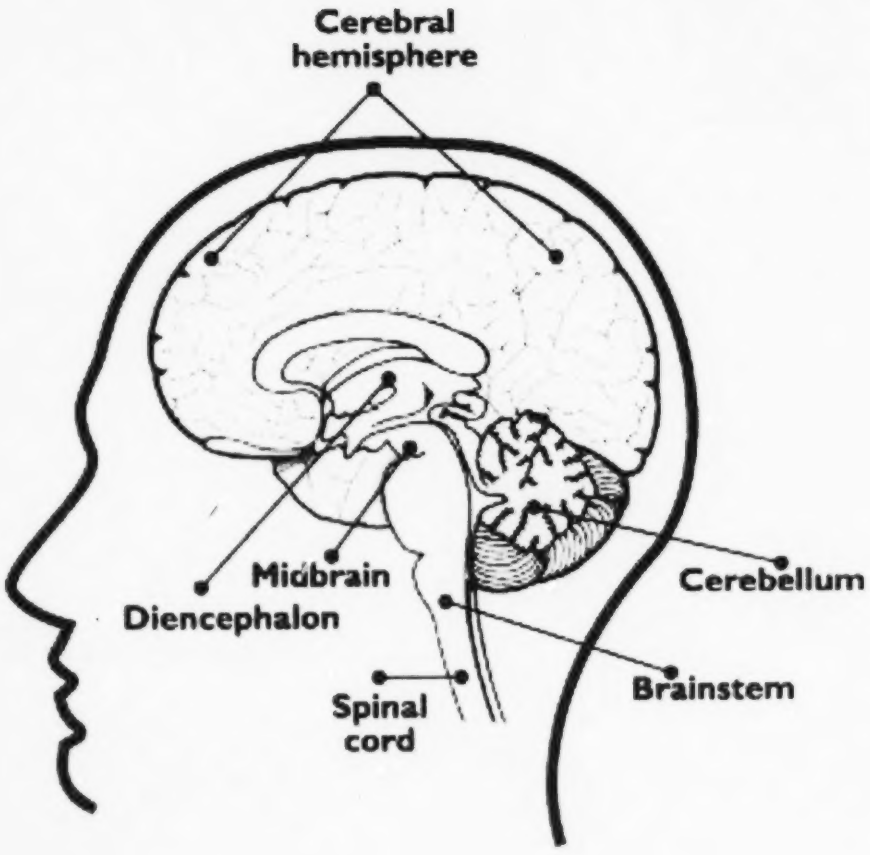

Cerebral hemisphere
Midbrain
Diencephalon
Cerebellum
Brainstem
Spinal cord

Figure 2

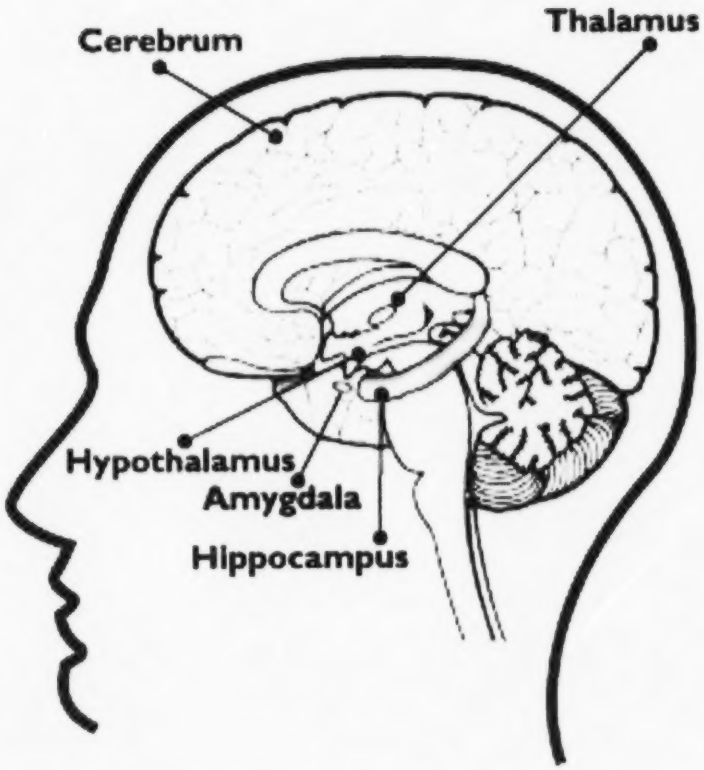


Figure 3

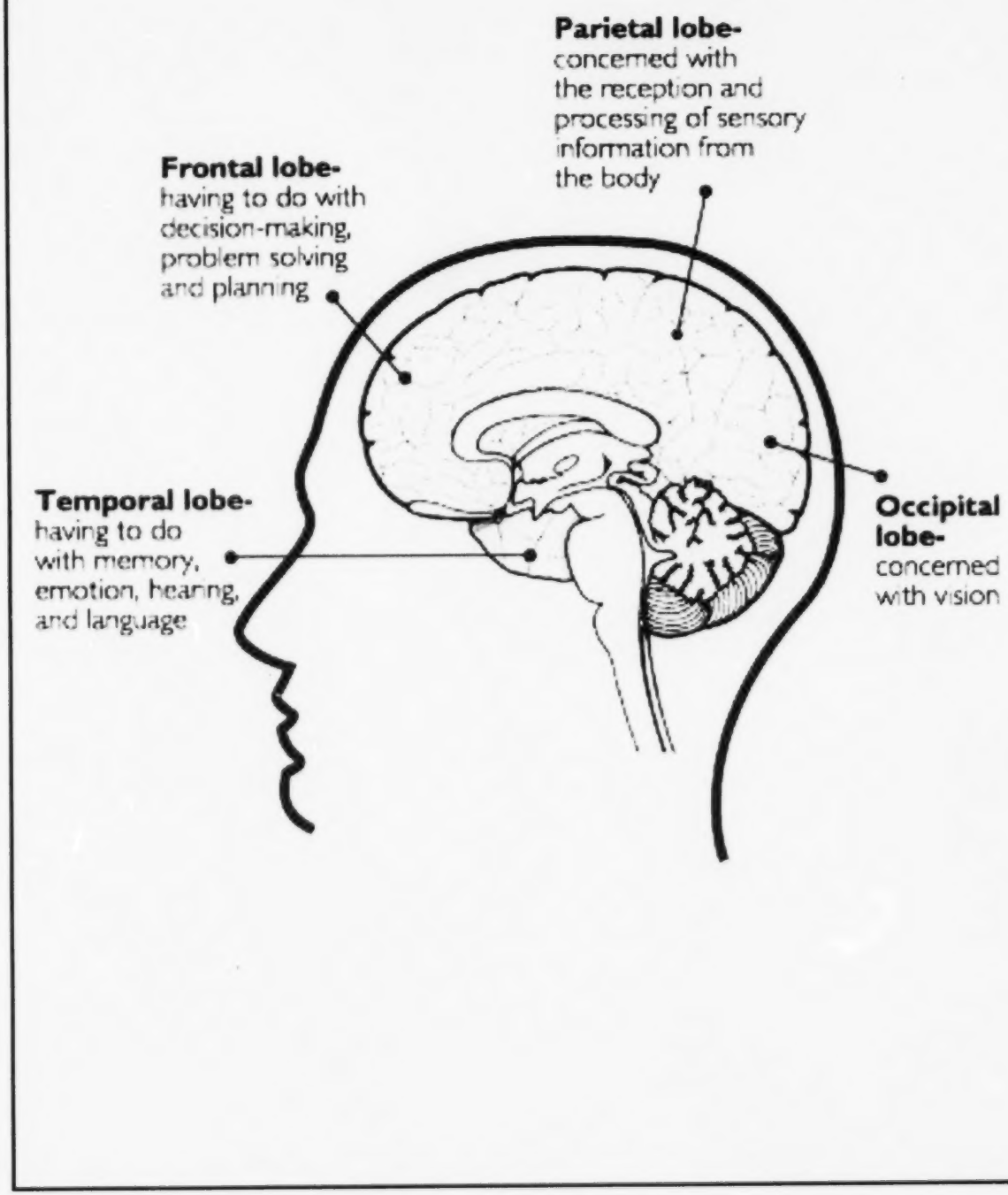

Parietal lobe-
concerned with the reception and processing of sensory information from the body
Frontal lobe-
having to do with decision-making, problem solving and planning
Temporal lobe-
having to do with memory, emotion, hearing, and language
Occipital lobe-
concerned with vision

Figure 4

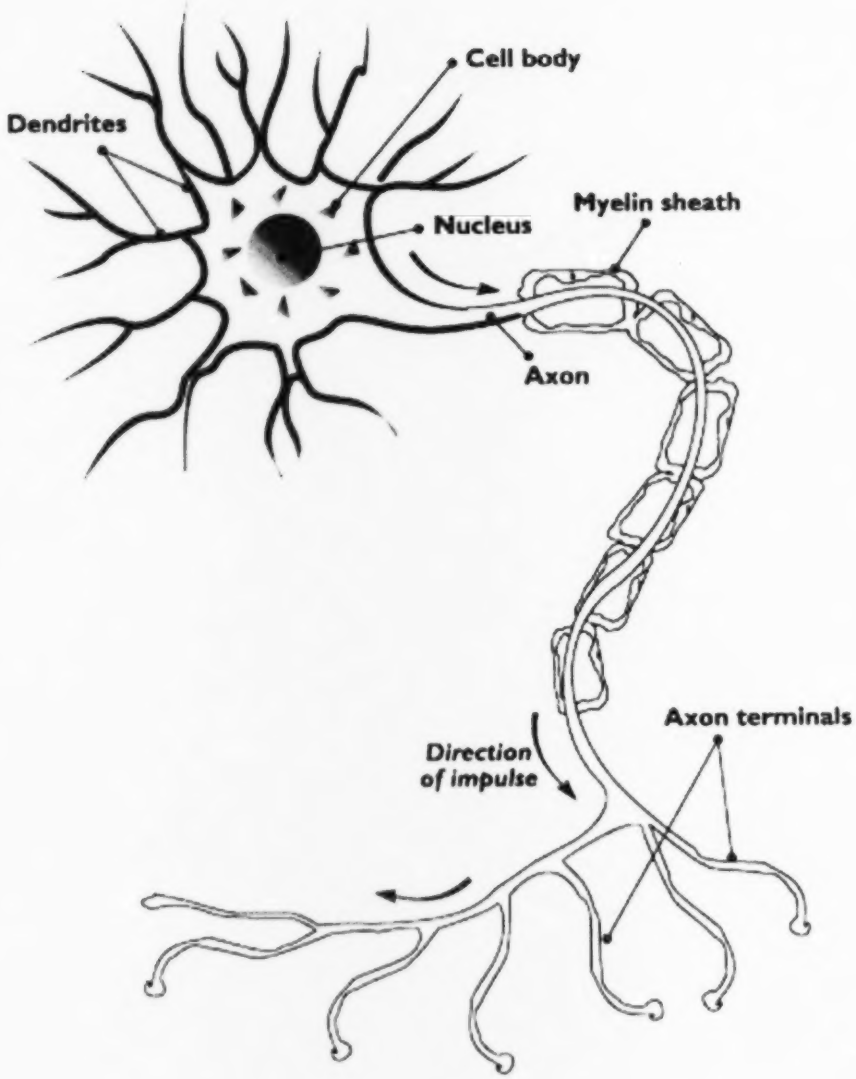

Cell body
Dendrites
Myelin sheath
Nucleus
Axon
Axon terminals
Direction of impulse

Figure 5

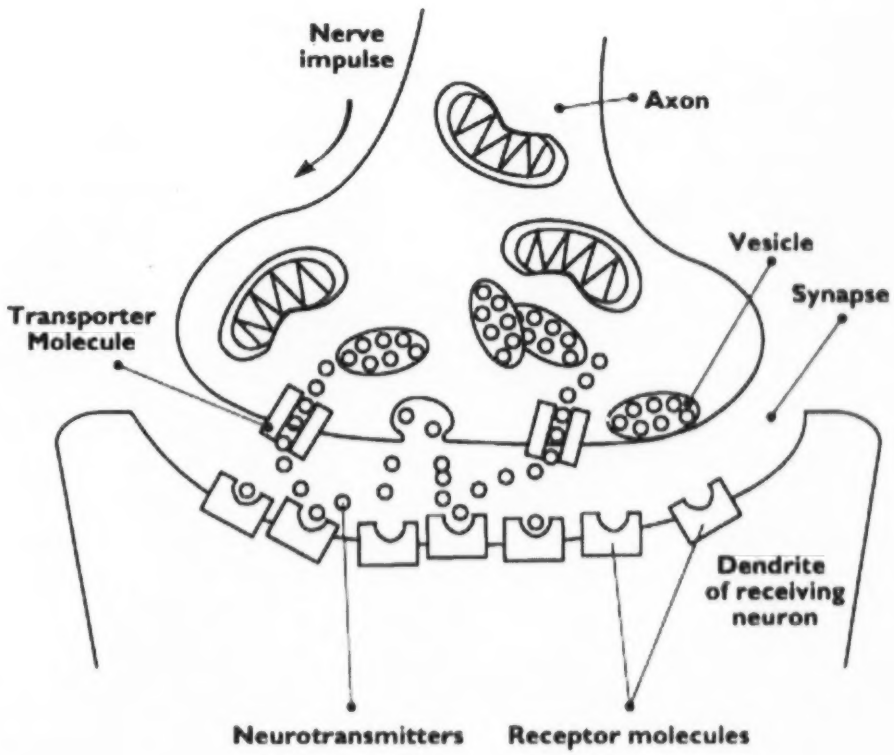

Nerve impulse
Axon
Vesicle
Synapse
Transporter Molecule
Dendrite of receiving neuron
Neurotransmitters
Receptor molecules

Figure 6

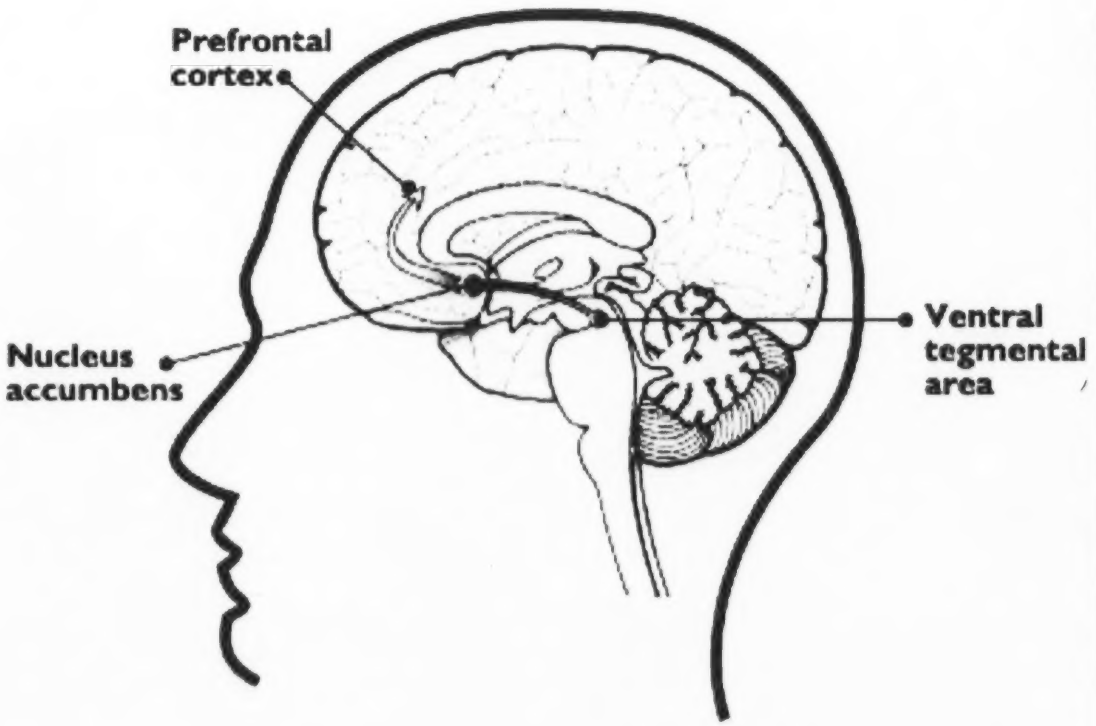
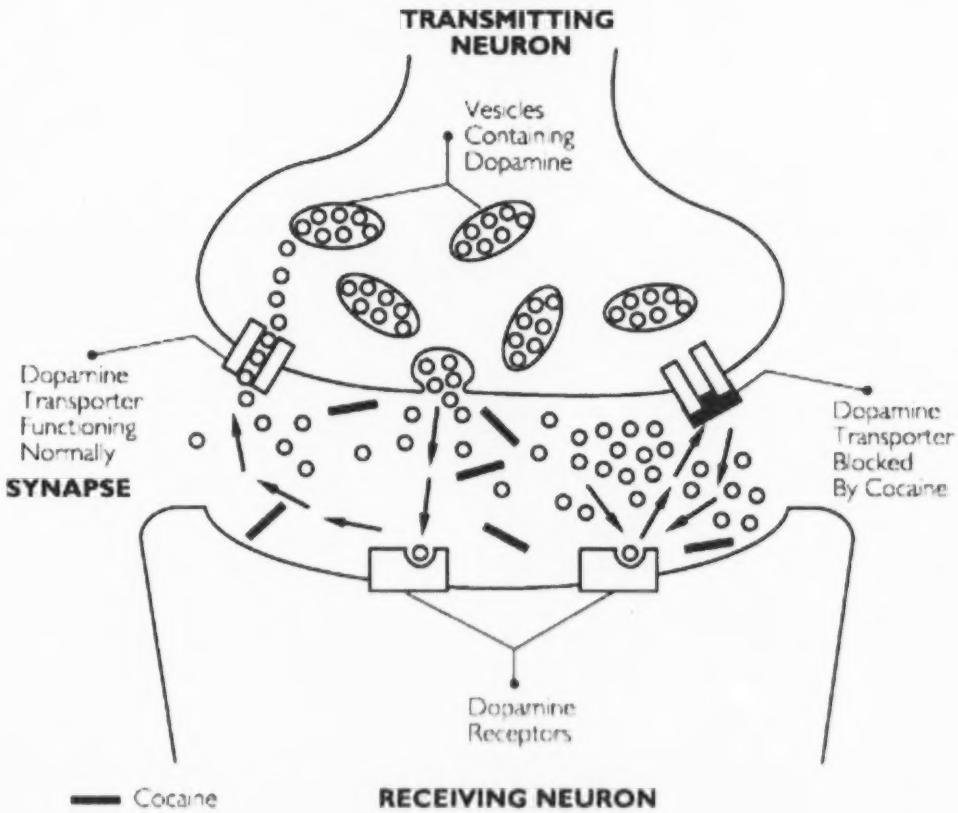
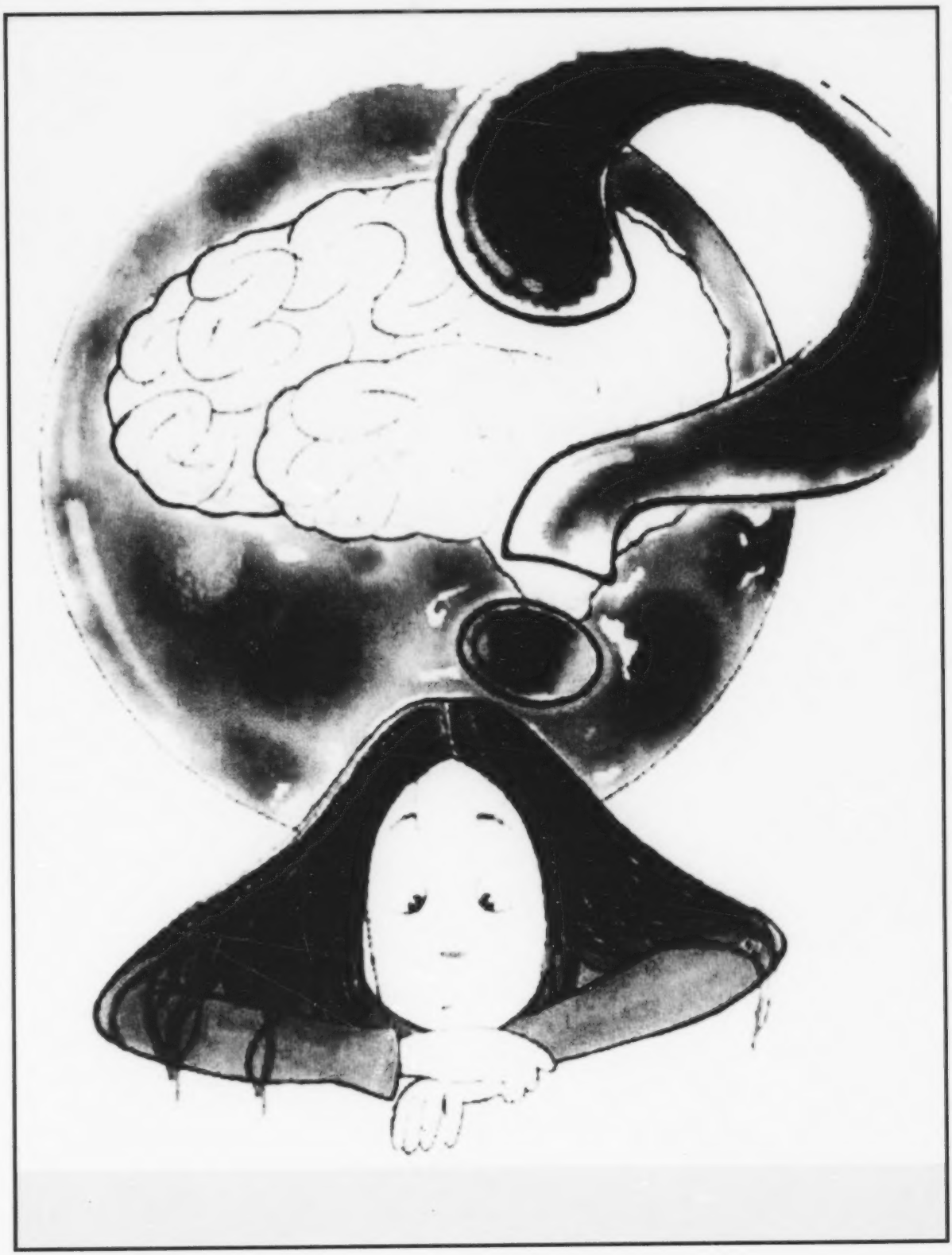

Prefrontal cortex
Nucleus accumbens
Ventral tegmental area

Figure 7


TRANSMITTING NEURON
Vesicles Containing Dopamine
Dopamine Transporter Functioning Normally
SYNAPSE
Dopamine Transporter Blocked By Cocaine
Dopamine Receptors
Cocaine
RECEIVING NEURON



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